



Analysis of wading bird use of impounded
wetland habitat on the Kennedy Space Center /
Merritt Island National Wildlife Refuge 1987-
1998

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Abstract

This report summarizes results of the first eleven years (1987–1989) of monthly aerial surveys of wading bird use of foraging habitats within impoundments on the Kennedy Space Center/Merritt Island National Wildlife Refuge (KSC/MINWR). Thirteen impoundments were surveyed continuously since the beginning of the effort; additional impoundments have been added since. Beginning in 1992, an effort was begun to install water control structures to reconnect almost all impounded salt marsh habitat on KSC/MINWR with the Indian River Lagoon System estuary (IRLS). However, management practices at KSC/MINWR were slow to incorporate changes that took full advantage of this potential. Thus, during the majority of the period covered by this report the study impoundments were effectively isolated from the IRLS.

During this study, some impoundments at KSC/MINWR were used much more heavily by wading birds than were others. Analysis of habitat within these impoundments suggests that the ratio of open water to vegetated habitats explains some of the variability in use between impoundments. This ratio is a measure of the interspersedness of habitat types within impoundments. Preliminary analysis suggests that an increase in interspersedness of open water and vegetated habitats is preferred by wading birds for foraging habitat. More detailed investigation of the mechanism responsible for wading bird preferential use of some impoundments is needed.

Over all impoundments, wading birds used open water habitat more often than would be expected based on availability if they used all habitats equally. Conversely, wading birds were observed in vegetated habitats less often than expected based on availability if they used all habitats equally. Many wading bird species increased their use of vegetated habitat in Fall and Winter when impoundments at KSC/MINWR are flooded. These shifts may represent important elements in overall foraging strategies of these species. Managers should not assume that a simple increase in open water habitat at KSC/MINWR would benefit wading birds.

The mean density of foraging wading birds observed in thirteen focal impoundments during the study was 0.566 individuals / ha (SD 0.169). There was no clear pattern in the yearly mean numbers of wading birds observed during the eleven years; this may be due to insufficient time-span given the amount of variation in the data. There were some

indications that certain species showed a slight decline in numbers during this period during at least some seasons. Species that warrant additional monitoring include White Ibis, Snowy Egret, Glossy Ibis, Tricolored Heron, Little Blue Heron, and Wood Stork. The mean number of wading birds per survey in the focal impoundments was greatest during the Pre-nesting and Nesting seasons, declined during Post-nesting season, and was lowest during Winter. Post-nesting and Winter are characterized by high water levels within impoundments at KSC/MINWR. During these times, shallow habitat along the IRL shoreline provided additional alternative habitats for wading birds.

Various measures of monthly precipitation and impoundment water level were well correlated with the numbers of wading birds observed during this study. Prior rainfall variables were more highly correlated than were measures of water depth. Rainfall data and water depth within the impoundments were fairly well correlated.

Numbers of nesting attempts by wading birds at KSC/MINWR was steady during the study period, with the exception of an unusually high number of attempts in 1990. White Ibis accounted for over half of all wading bird nests counted during the study. The mean number of nests per colony decreased during the study period, and the number of individual colonies increased. A similar pattern has been reported for wading bird nesting colonies throughout Florida between 1976 and 1989. Combined with the overall decline in numbers statewide these trends are alarming and continued monitoring of wading bird nesting colonies on KSC/MINWR is warranted. Evidence for decline in the numbers of nesting Snowy Egret, Glossy Ibis, Little Blue Heron, and Wood Stork on KSC/MINWR warrant special concern for these species.

For five species of wading bird (White Ibis, Snowy Egret, Glossy Ibis, Tricolored Heron, Little Blue Heron, and Wood Stork) trends in the number of individuals observed foraging within impoundments over the eleven years of study indicate that more intensive monitoring may be needed. For four species of wading bird (Snowy Egret, Glossy Ibis, Little Blue Heron, and Wood Stork) trends in numbers of nesting attempts observed during the study may warrant more intensive monitoring.

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Introduction

Most species of wading birds in Florida have experienced great reductions in population sizes during the last century, due to a long history of persecution, habitat loss, and habitat alteration (Ogden 1978, 1994, Frohing et al. 1988). Complicating interpretation of population declines in the southeastern United States, tremendous geographical shifts in the distribution of wading bird populations have occurred during the last several decades (Ogden 1994, Fleury and Sherry 1995, Frederick et al. 1996, Frederick and Ogden 1997). These changes have been attributed to changes in management of wetlands (especially hydrology) in the regions involved (Bancroft et al. 1994, Frederick and Spalding 1994, Ogden 1994). As a result of these population trends, many species of wading birds are listed as species of special concern by the Florida Fish and Wildlife Conservation Commission (Wood 1996). If managers are to conserve wading bird populations in Florida, more information is needed on long-term trends in wading bird numbers in key habitats throughout the state.

Wading birds are intricately tied to their wetland habitats, which provide resources for all aspects of their existence. Unfortunately, wetland loss in Florida has occurred at a staggering rate (Kautz 1993). Many experts agree that the greatest current threat to wading bird populations in Florida is the continued loss and alteration of wetland habitat in the state (Runde 1996, Rodgers 1996, Ogden 1996a, 1996b, Kushlan 1997, Frederick and Spalding 1994, Hoffman et. al. 1994, Ogden 1994). With a constantly expanding human population, it does not seem likely that the pressure on natural wetland habitats in Florida will ease soon (DeFreese 1991). It is clear that the future of wading birds in Florida is tied to protection of wetlands, and where possible multi-species or integrated management.

To help reverse declines in wading bird populations, a clearer understanding of several features of their ecology is needed, including the factors determining wading bird foraging success, how management influences prey populations, and the role of wetland habitats in supporting wading birds. This study addresses these questions for wading birds foraging in impounded wetlands on the Kennedy Space Center/Merritt Island National Wildlife Refuge. This site is recognized as an important area for wading birds in the Southeastern United States (Crucikshank 1980, Mikuska et al. 1998). Because it is

protected from wide scale development, it serves as a base-line for comparing population trends with other areas in the region. The objective of this study was to investigate how wading bird foraging use varied among different habitat types in impounded wetlands. The study also initiated a long-term monitoring program for wading birds Kennedy Space Center/Merritt Island National Wildlife Refuge. This study will also begin to develop the ability to detect trends in population numbers, and to investigate the effects of management on wading bird habitat use at KSC/MINWR.

Background

The Kennedy Space Center/Merritt Island National Wildlife Refuge (KSC/MINWR) is located on the Atlantic coast of Florida, and encompasses a large portion of the northern part of the Indian River Lagoon System (IRLS). Stretching for ca. 250 km from Ponce de Leon Inlet to Jupiter Inlet, the IRLS is an important site for wading birds on the southeastern Atlantic coast of North America (Schikorr and Swain 1995, Sewell, et al. 1995, Smith and Breininger 1995). The IRLS is a sub-tropical estuary with an unusually high level of biodiversity due to its location at the junction of the warm-temperate Carolinian Province and the Tropical Caribbean Province (Gilmore 1995, Breininger et al. 1998). Historically the eastern margin of the IRLS was extensively vegetated with irregularly flood salt marsh habitat (Schmalzer 1995). Almost all salt marsh in the northern part of the IRLS was impounded for mosquito control by the 1970's (Brockmeyer et al. 1997). Some species of wading birds appear to have benefited from the changes in habitat resulting from impounding (Provost 1969, Breininger and Smith 1990, Smith & Breininger 1995, Schikorr & Swain 1995), while other species of waterbirds have declined (e.g. Dusky Seaside Sparrow, Black Rail). A recent effort to reconnect much of this impounded salt marsh habitat with the estuary is underway (Brockmeyer et al. 1997); the effects of reconnection on wading bird populations are unknown.

KSC/MINWR contains ca. 70 shallow impoundments in former salt marsh habitat. Human impacts on saline and brackish marshes of Merritt Island began as early as 1926 when ditches were dug to drain marsh surfaces to reduce oviposition by *Aedes* mosquitoes. Following World War Two, mosquito control efforts turned to intensive

spraying of DDT in the 1940's; however rapid evolution of pesticide-resistance rendered the use of DDT ineffective, and increasing public concern for risks associated with it's use lead to the search for an alternative means of mosquito control. A solution to the problem was found through impounding the salt marsh habitats that breed mosquitoes (Provost 1969). The success of impounding salt marsh for mosquito control in the IRLS culminated in the impoundment of nearly all of the marshes bordering the Indian River and the Mosquito Lagoon by 1970. Permanent flooding of these impoundments changed the characteristics of the wetland habitats within, prompting a profound change in vegetative and avian communities (Provost 1969, Schmalzer 1995, Brockmeyer et al. 1997).

Specific effects of impounding on salt marsh habitat varied between locations. Ecological changes in some impoundments included a decrease in salinity levels resulting from isolation from wind-driven tides and trapping of rainwater, or in some impoundments, due to artesian wells. In other impoundments, salinity was greatly increased due to evaporation of water pumped in from the lagoon. Such changes in water quality coupled with isolation from the lagoon resulted in changes in the fish and invertebrate populations within impoundments (Brockmeyer et al. 1997). Impact was not limited to the time period immediately following impoundment. Long-term changes in vegetative and physiographic conditions continue in the impounded wetlands.

Among the most notable recent change in impounded wetland habitats has been the decrease in open water habitats as cattail (*Typha* spp.) became dominant in shallow, low salinity impoundments with limited management capability (Breininger and Smith 1990, Smith and Breininger 1995). Managers at KSC/MINWR have been very successful in reducing the amount of cattail coverage in impoundments where reconnection has begun. Due to such changes within impoundments, some have expressed concern that isolation of wetland habitat from the IRLS has resulted in a net loss of ecological benefits (e.g. nursery habitat for estuarine organisms, habitat for wildlife, water quality). Currently, efforts are underway which will reconnect over three-quarters of all impounded wetlands in the Indian River Lagoon System (Brockmeyer et al. 1997), the majority of impoundments at KSC/MINWR (Marc Epstein, pers. comm.). It is unclear what effect this will have on the wading bird populations that now utilize KSC/MINWR.

KSC/MINWR supports a large wading bird population that utilizes freshwater and salt marsh habitats for feeding, roosting, and nesting (Smith and Breininger 1995). The KSC/MINWR wading bird population consists of 16 species, all but one of which (the American Bittern, *Botaurus lentiginosus*) are year-round residents (Stevenson and Anderson 1994). Large numbers of wading birds breed on spoil islands of the Indian River, Banana River, and Mosquito Lagoon (Smith and Breininger 1995). In addition, large numbers of several species of wading birds from more northern portions of their ranges winter on the refuge (Crucikshank 1980). Previously, two small islands within KSC/MINWR near the west end of Banana Creek at the Indian River supported a large mixed species wading bird colony that included Wood Storks. This colony annually included from 100 to over 300 pairs of Wood Storks until 1981 when a freeze killed the mangroves in which the birds nested (Girard and Taylor 1979, Rodgers et al. 1987). Although they no longer nest on KSC/MINWR, many Wood Storks forage in wetland habitats on the refuge.

Methods

Surveys

Wading bird foraging surveys - Wading bird habitat surveys included in this analysis were conducted between April 1987 and September 1997. Surveys were conducted between the hours of 0900 – 1200 EST, in a NASA Huey helicopter flying at an altitude of approximately 60 m, and a speed of 60 kn. The sampling schedule for surveys was one per month, although some months were missed due to constraints on use of the NASA helicopter. Roughly 20 % of the nearly 11,000 ha of impounded marsh habitat and 16% of the estuarine/river boundary occurring on KSC/MINWR was surveyed (Figure 1). Thirteen impoundments (referred to as focal impoundments hereafter) were surveyed between April 1987 and September 1997; four additional impoundments were added to the monthly surveys in August 1993 (all seventeen impoundments are referred to as study impoundments hereafter). Impoundments were flown systematically such that all area within was observed, and all individuals visible within the impoundment were counted. Estuarine edge was surveyed by flying approximately 300 m from the shore and included observations within this 300 m strip. Roughly 72 km of estuarine edge was

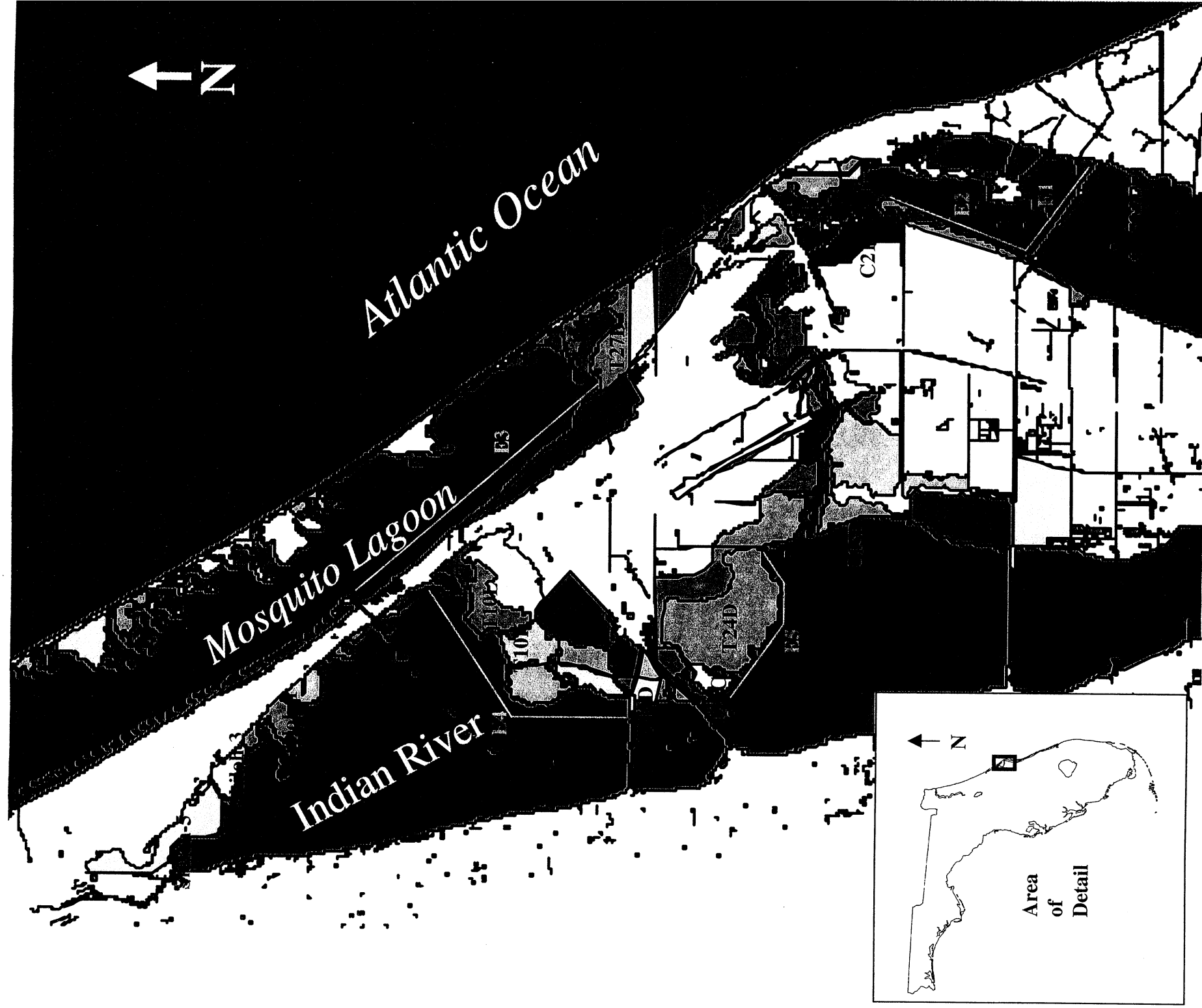


Figure 1. Impoundments on the Kennedy Space Center/Merritt Island National Wildlife Refuge. Study impoundments are labeled in red. Study shoreline sections are labeled in green.

surveyed for a total area of approximately 2160 ha. Data collected for each individual or group of wading bird observed was: species, cover type, and for estuarine edge the estimated distance to the shore. Cover types included: Open Water, Cattail (*Typha* spp.), Spartina (*Spartina alterniflora*), Juncus (*Juncus roemerianus*), Distichlis (*Distichlis spicata* or *Sporobolus virginicus*), Mangrove (*Avicennia germinans*, *Laguncularia racemosa*, or *Rhizophora mangle*), Grass (unknown marsh grass), Emergent (unknown emergent), Pipe (artificial perch), or Unknown (unidentified cover type).

Colony Counts

The number of nests by species was estimated yearly between 1987 and 1989, except no data was recorded in 1991. Each nesting season, a preliminary helicopter survey was flown in March or early April to identify all nesting sites occurring on KSC/MINWR. Small colonies were counted from the air during that survey and also during the foraging surveys; the highest count was used for that year's nesting total. Only birds associated with a nest were counted. Colonies that were too large to be counted from the air were visited once during April/May by boat. The boat traveled slowly around the island at a distance of approximately 100 m, while two or three observers counted nests using binoculars.

Habitat Selection Analysis

We determined the composition of habitats within each study impoundment based on a 1:24,000 scale comprehensive land cover map developed from photo interpretation of vegetation mapped with a 2-acre resolution (Larson and Swain, unpublished GIS map dated 1991). This map used the Florida department of transportation FLUCS codes to designate land cover types. Use of land cover data from the beginning of the study period may have resulted in poor characterization of available wading bird habitat within impoundments over the eleven years of the study. Also, the single map did not capture any seasonal or inter-year hydrologic changes that occurred within impoundments over the study. We chose to use this map as a tool in the initial exploratory data analysis since no more recent information was available.

Broad habitat categories were formed by combining several of the land cover types

from the map. Wetland was calculated as the total amount of wetland cover types within the impoundment and included the categories: marsh/swale, open water, salt marsh, tidal swale, and wetland forest. This category may have underestimated the amount of wetland habitat because we chose not to include the category labeled disturbed shrubs/exotic. Marsh was the sum of all herbaceous, non-woody wetland vegetative cover within the impoundment, and included the categories marsh/swale, salt marsh, and tidal swale. Open Water was the amount of open water mapped within each impoundment. The ratio of Marsh to Open Water was calculated for each impoundment (referred to as Ratio).

Correlation analysis between wading bird use and habitat, rainfall and water levels were performed for the 10 most abundant wading bird species. We grouped the ten species into functional groups based on foraging ecology and feeding behavior. Piscivores consisted of Snowy Egret (*Egretta thula*), Great Egret (*Egretta alba*), Tricolored Heron (*Egretta tricolor*), and Reddish Egret (*Egretta rufescens*). Probers were White Ibis (*Eudocimus albus*) and Glossy Ibis (*Plegadis falcinellus*). Little Blue Herons (*Egretta caerulea*) were considered separately as Invertebrate Specialists. Both Wood Storks (*Mycteria americana*) and Roseate Spoonbills (*Ajaia ajaja*) were also considered separately. For each of the 5 functional groups we calculated the Spearman rank correlation coefficients between density and habitat within impoundments for each of the four habitat categories.

Rainfall and Impoundment Water Level Data

Monthly rainfall totals were obtained from the Merritt Island National Wildlife Refuge Annual Narratives (Merritt Island National Wildlife Refuge, unpublished Annual Narratives 1987 through 1997). This data was collected at the NASA Shuttle Landing Facility weather station, which is within 30 km of all of the study impoundments. Monthly impoundment water depth measurements were obtained from Merritt Island National Wildlife Refuge staff. This data was available for most of the study impoundments for the period February 1993 through May 1996. No data was available for impoundments C15D, C21B, or T9.

Rainfall and water level values were combined to form several new variables for use

in correlation analysis. Each functional group was used as a dependent variable in a separate analysis. Natural logs of the numbers of individuals within groups were used to make the distributions more normal. Independent variables used in analysis were of two types, rainfall and water depth within the impoundments. Rainfall variables included were: monthly rainfall, the prior month's rainfall, and three different moving averages which included the current month (two-month, three-month, and four-month moving averages). We used square root data transformations to make the rainfall variables more normal. Impoundment water depth was based on the mean depth in all study impoundments combined (excluding outliers). Depth measures included the current month's mean depth, and three measures of depth change. LAG was the difference between the current and the previous month's mean depth. LAG2X was the difference between the second and third previous month's mean depth. LONGLAG was the sum of the depth change over the previous three months (LAG + LAG2X). No data transformations were used with the water depth variables because these variables appeared to be distributed normally.

Results and Discussion

Survey Effort

A total of 96 surveys were flown between April 1987 and September 1997. The coverage of surveys between seasons was fairly even (mean number surveys per month were: Pre-nesting 8, Nesting 9.3, Post-nesting 9.3, Winter 6). Some potential problems with temporal coverage were: 1) fewer surveys were conducted during winter months and 2) unevenness in the number of surveys between years (mean number of survey / year = 8.7, 2.2 SD). The reason for the high variability in the mean number of surveys per year was that only four surveys were flown in 1997. This poor coverage was due to a lapse in NASA Flight Operations support during government shutdowns that year. Patterns of temporal coverage of wading bird aerial foraging surveys were considered in interpretation of the results discussed below.

Impoundment Use

Wading bird use varied greatly between impoundments (Figure 2); this pattern is

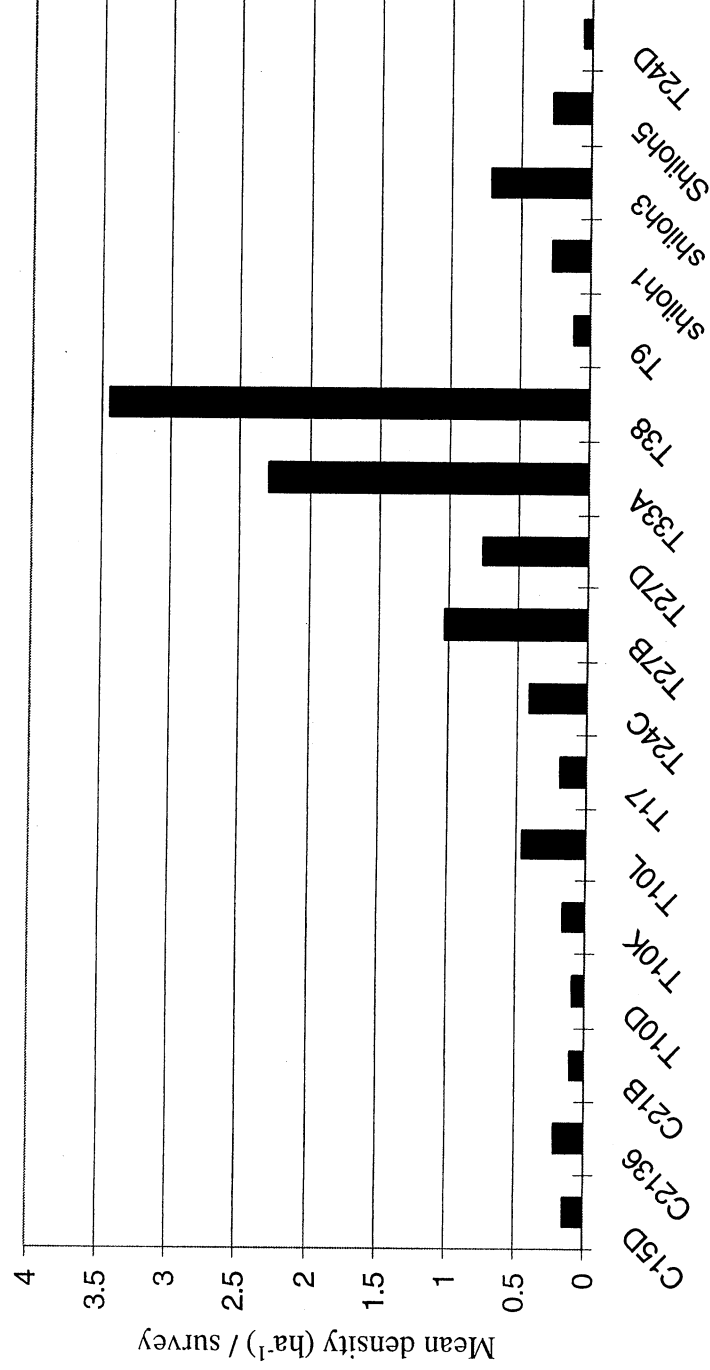
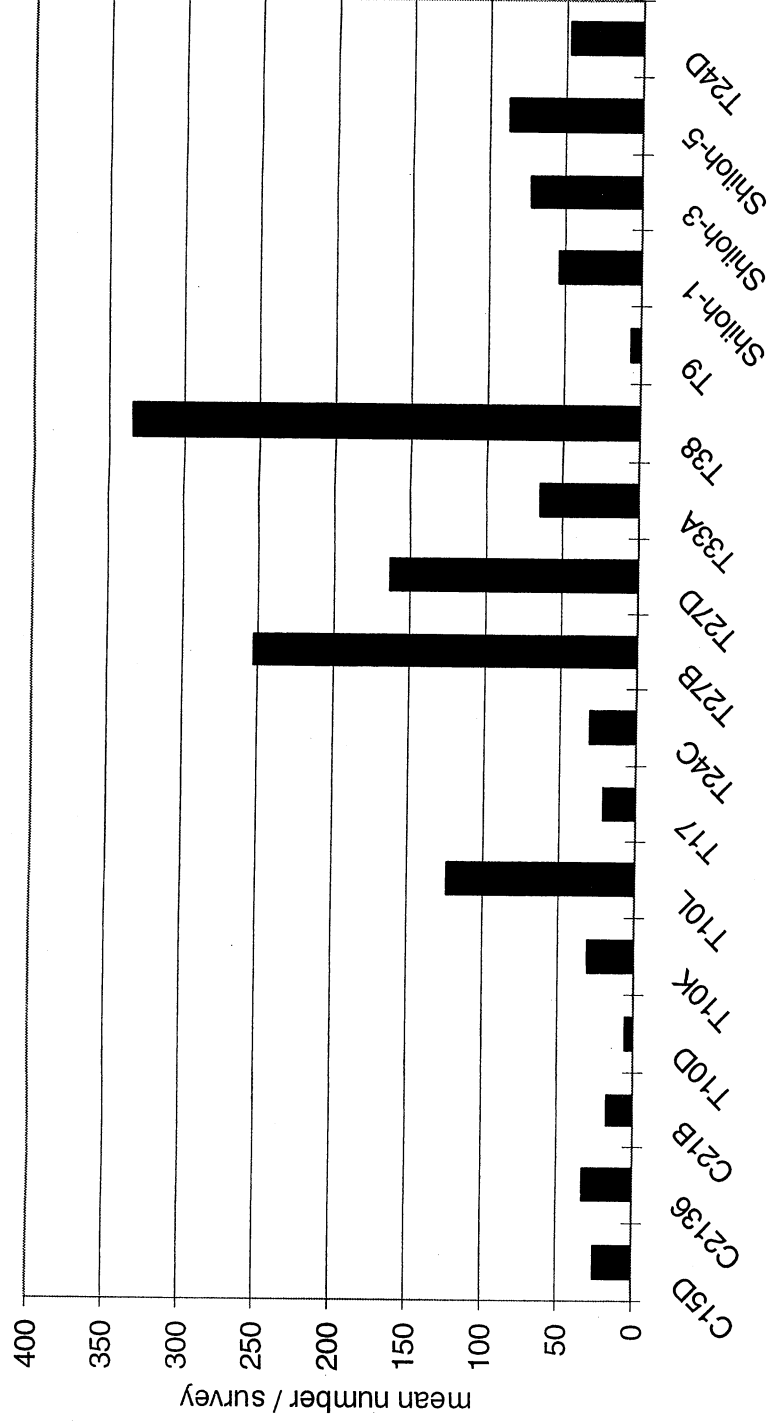


Figure 2. Above, average number of individuals per survey for all species of wading birds combined for seventeen study impoundments at MINWR observed during foraging surveys from April 1987 through September 1997. Below, average density of individuals per survey for all species of wading birds combined for seventeen study impoundments observed during foraging surveys from April 1987 through September 1997.

probably one of the most significant features of the distribution of wading birds on KSC/MINWR. Some impoundments were used regularly by several species of wading bird over the majority of surveys. Other impoundments were rarely used by wading birds during the study period. Four of the impoundments stood out as having consistently higher numbers of wading birds: T38, T27B, T27D, and T10L. Three of these (T38, T27B, and T27D) were clustered in close proximity on the southern end of the Mosquito Lagoon. The fourth impoundment, T10L, was approximately 20 km northwest of this group, and is located on the Indian River Lagoon. A fifth impoundment, T33A, was second in use based on the density of individuals / survey; T33A was also located at the south end of the Mosquito Lagoon near T38, T27B, and T27D.

Differences in habitat availability within impoundments may explain some of the differential use of impoundments by wading birds. All of the top-ranked impoundments for wading bird use (T38, T27B, T27D, T10L, T33A, Shiloh 3, and Shiloh 5) have relatively smaller marsh to open water ratios than do the less used impoundments (Figure 3). The pattern of habitat use by wading bird functional groups was well correlated with the ratio of marsh to open water habitat within the impoundments (Table 1); for all groups the density decreased as the ratio increased. This pattern was not due to the absolute amount of either habitat type within the impoundment. The ratio of marsh to open water is a measure of the interspersed of habitat types, which may be an index of prey production or availability within the impoundment.

The mean density of foraging wading birds observed in the thirteen focal impoundments during the study was 0.566 individuals / ha (SD 0.169). The density of wading birds at KSC/MINWR, even in the most used impoundments (Figure 2), was very low compared to those reported by Sewell et al. (1996) for impoundments in St. Lucie County. However, the latter study measured wading bird density during experimental drawdown events designed to attract wading birds to the impoundments. Densities of wading birds foraging in the upper St. John's River marshes were similar to densities in this study (calculated from data in Hoffman (1996): mean density for all species over all surveys = 1.57 individuals / ha, S.D. = 0.76, max = 3.56, min = 0.68). Density of wading birds foraging along the IRLS shoreline during this study was similar to the density within most impoundments. Assuming a survey area of approximately 1260 ha (72 km

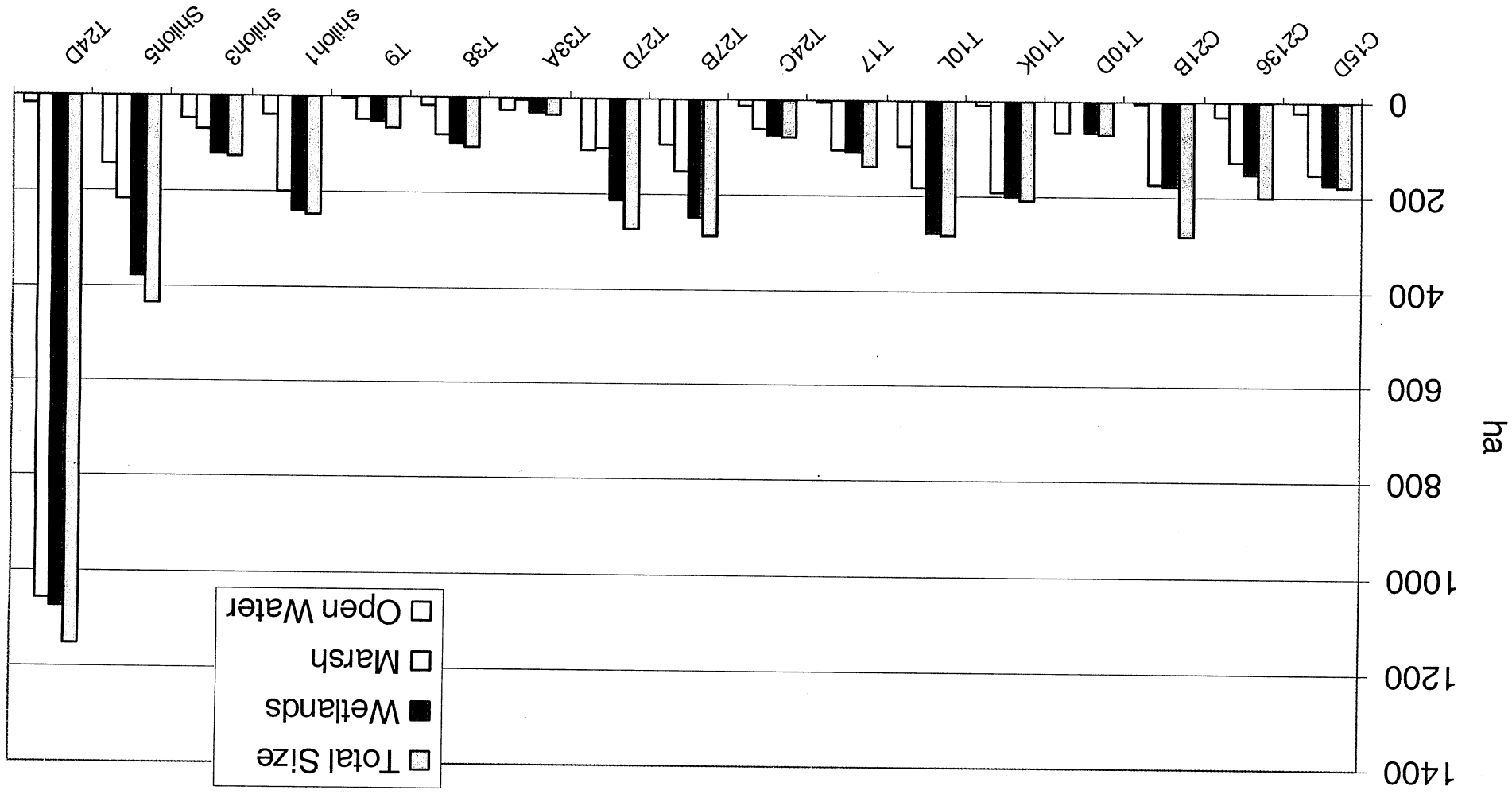


Figure 3. Habitat of seventeen study impoundments at KSC/MINWR, mapped by Larson and Swain (1990).

Table 1. Results of Spearman Rank Correlation analysis between bird use and habitat characteristics of 16 study impoundments at MINWR.

Functional Group		Total Habitat		Open Water	Ratio	Marsh
Probers	Correlation Coefficient	-0.20		0.27	-0.44	-0.36
	Sig. (1-tailed)	0.22		0.15	0.04	0.08
	N	17		17	17	17
Piscivores	Correlation Coefficient	-0.09		0.55	-0.67	-0.26
	Sig. (1-tailed)	0.37		0.01	0.00	0.16
	N	17		17	17	17
Little Blue Heron	Correlation Coefficient	-0.15		0.38	-0.52	-0.30
	Sig. (1-tailed)	0.28		0.06	0.02	0.12
	N	17		17	17	17
Roseate Spoonbill	Correlation Coefficient	0.03		0.41	-0.46	-0.09
	Sig. (1-tailed)	0.45		0.05	0.03	0.36
	N	17		17	17	17
Wood Stork	Correlation Coefficient	-0.23		0.25	-0.40	-0.32
	Sig. (1-tailed)	0.19		0.16	0.06	0.10
	N	17		17	17	17

surveyed x 300 m transect width), the mean density of wading birds observed along the IRL shoreline was 0.045 individuals/ha. This is comparable to the density in most of the impoundments, but much lower than that in the impoundments with the highest wading bird use (e.g. T38, T33A, T27B, T27D, Shiloh-3).

Rainfall and Hydrology

During most years, the total yearly rainfall recorded was above the long-term average, but during 1990, 1992, and 1993 the totals were below. The monthly rainfall averages were variable, but the 4-month average (the mean of the current month and the previous three month's total rainfall) closely followed seasonal patterns of water depth in the impoundments (Figure 4). This pattern of high water levels in late fall through winter with a gradual decline in level in spring is characteristic of the water level in the IRLS (Provost 1973). The fact that the water depths within the impoundments closely followed the pattern of 4-month average rainfall suggests that rainfall determined the water depth within impoundments. This probably occurred due to a combination of direct interception and also runoff from adjacent uplands. It is important to remember that although water levels within the impoundments resembled seasonal changes in water depths in the IRLS, the magnitude of change in depth within the impoundments was much less than were changes in depth over salt marsh prior to impounding (Trost 1968). On average, impounded salt marsh on KSC/MINWR that is not hydrologically connected with the IRLS is now drier in winter and wetter in summer than occurred prior to impounding.

Several significant correlations were found between rainfall variables and the mean number per survey within functional groups for the 13 focal impoundments during the entire study period (Table 2). The mean number of individuals of all species per survey was negatively correlated with all variables that measured rainfall preceding the survey. Numbers of Probers were also negatively correlated with all variables that measured rainfall preceding the survey. Numbers of Piscivores were negatively correlated with two of the rainfall variables that measured rainfall preceding the survey, while numbers of Roseate Spoonbill were negatively correlated with monthly rainfall. There was no significant correlation between numbers of birds and rainfall variables for Little Blue

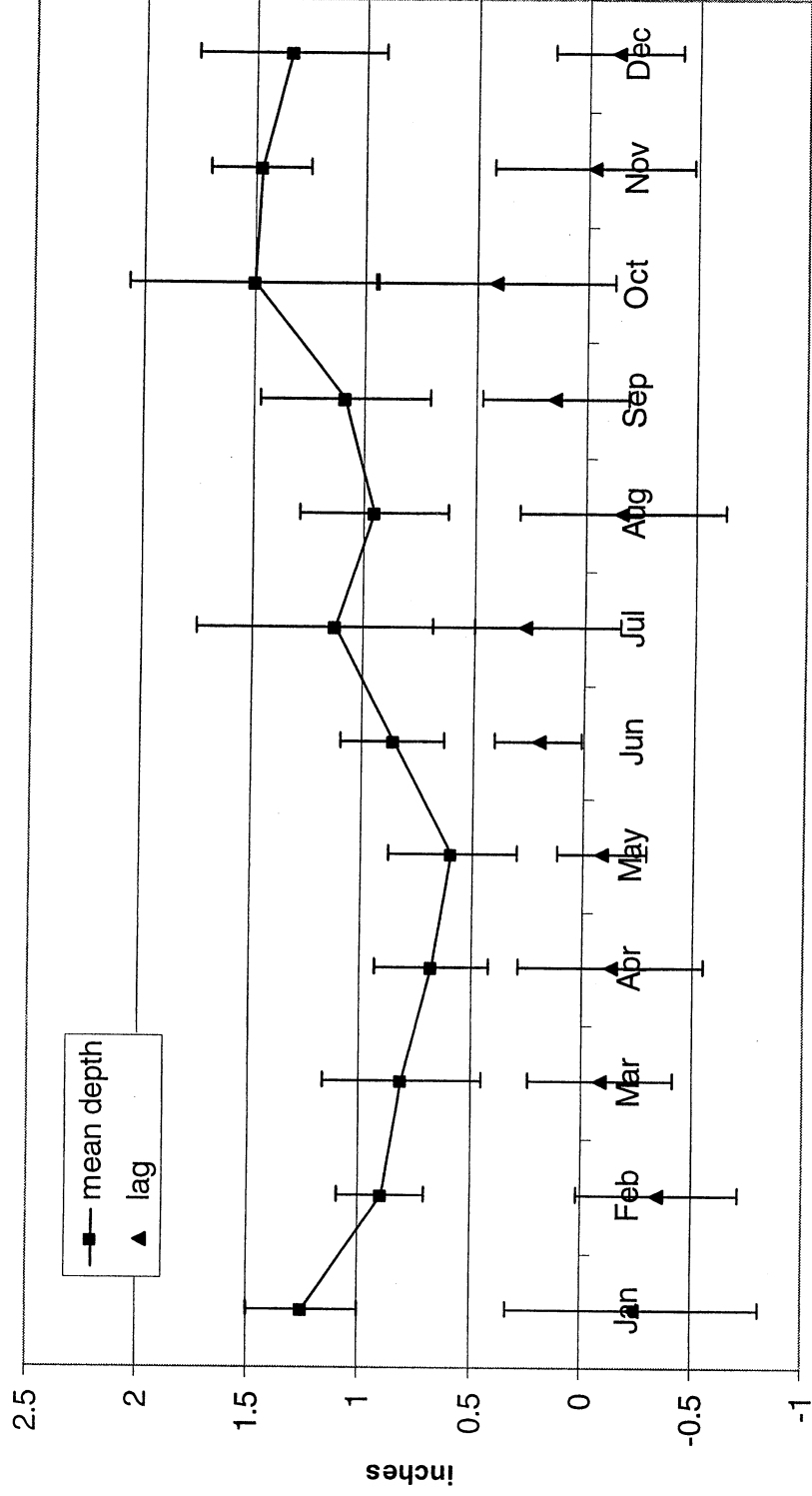
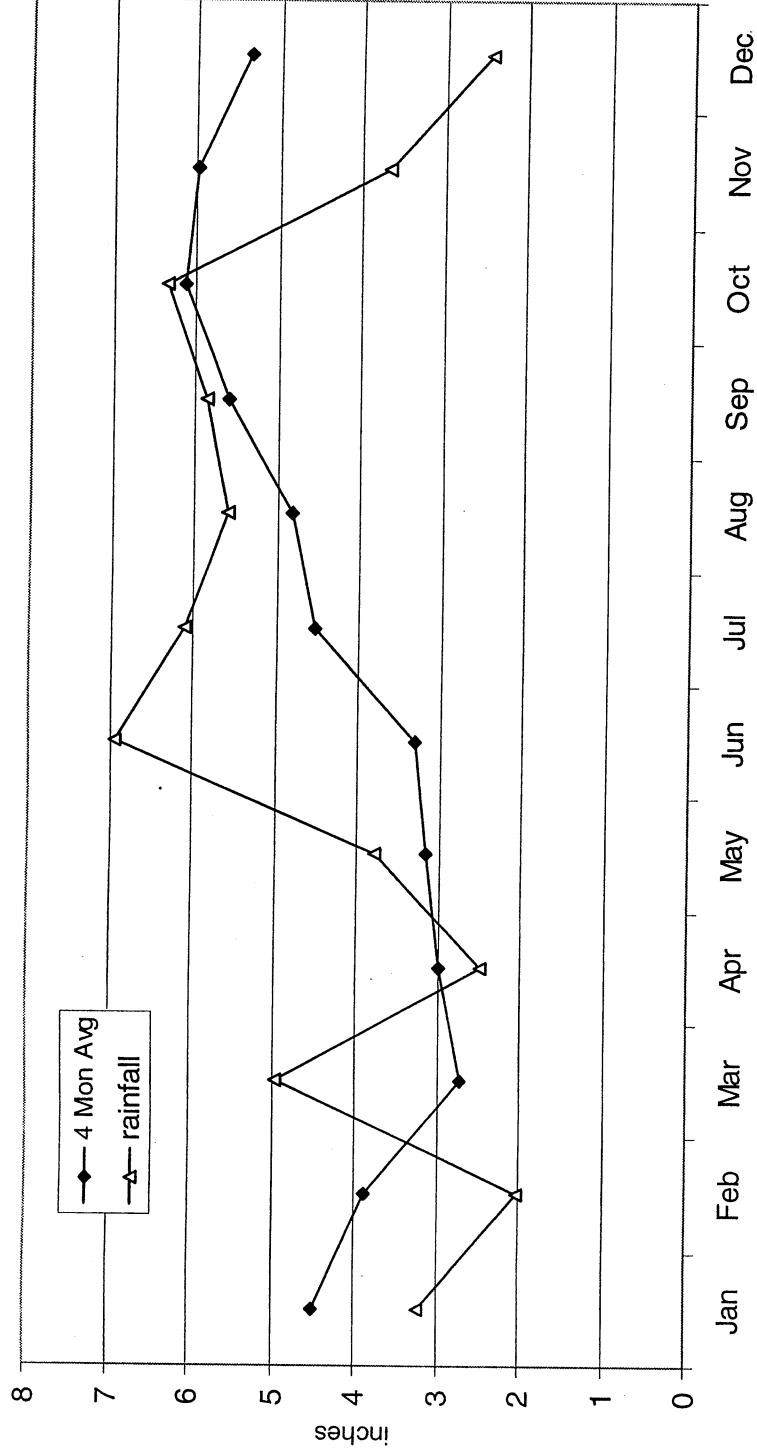


Figure 4. Above, mean monthly rainfall at MINWR from January 1987 through December 1997. Open triangles give mean monthly rainfall totals and closed diamonds give the prior 4 month average rainfall. Below, water depth within study impoundments between January 1992 and may 1996. Closed squares give the mean monthly observed water level within each impoundment, with error bars showing one standard deviation. Closed triangles give the mean monthly change (lag) in water level observed within each impoundment, with error bars showing one standard deviation.

Table 2. Results of correlation analysis between mean number individuals / survey and rainfall for wading bird foraging surveys in 13 focal impoundments at MINWR. (correlations in bold are significant at $\alpha = 0.01$). Rainfall variables were square root transformed, and all wading bird variables were natural log transformed to make distributions more normal.

Functional Group		monthly rainfall ^{1/2}	prior month's 2 month avg. ^{1/2}	3 month avg. ^{1/2}	4 month avg. ^{1/2}
LN(WBTOT)	Pearson Correlation	-0.04	-0.37	-0.35	-0.39
	Sig. (2-tailed)	0.689	0.000	0.001	0.000
	n	96	96	96	95
LN(Piscivores)	Pearson Correlation	0.02	-0.21	-0.21	-0.26
	Sig. (2-tailed)	0.871	0.038	0.041	0.011
	n	96	96	96	95
LN(Probers)	Pearson Correlation	-0.14	-0.45	-0.38	-0.41
	Sig. (2-tailed)	0.164	0.000	0.000	0.001
	n	96	96	96	95
LN(LBHE)	Pearson Correlation	-0.10	-0.18	-0.17	-0.20
	Sig. (2-tailed)	0.310	0.081	0.091	0.056
	n	96	96	96	95
LN(WOST)	Pearson Correlation	-0.02	-0.23	-0.19	-0.13
	Sig. (2-tailed)	0.876	0.022	0.071	0.218
	n	96	96	96	95
LN(ROSP)	Pearson Correlation	0.26	0.03	0.04	-0.04
	Sig. (2-tailed)	0.010	0.739	0.676	0.696
	n	96	96	96	95

Heron or Wood Stork. Correlation analysis of numbers of individuals within functional groups using impoundments, and the water depth variables revealed few correlations (Table 3).

Several previous studies have noted that the amount of wading bird foraging activity in a region is related to water depth and the amount of previous rainfall (e.g. Bancroft et al. 1994, Strong et al. 1997). Thus, it was not unexpected that measures of prior rainfall were well correlated with numbers of wading birds during this study. It is not clear why prior rainfall variables were more highly correlated than were measures of water depth. One possibility is that the time-span of the water depth data available was not sufficient to detect correlations between wading bird numbers and water depth. The rainfall data was fairly well correlated with water depth within the impoundments, and spanned over the entire study period. Thus prior rainfall may be thought of as an index of water conditions within the study site.

Temporal Trends

There were definite seasonal patterns in foraging wading bird abundance observed during the study. The mean number of wading birds per survey in the focal impoundments was greatest during the Pre-nesting (Feb – Mar) and Nesting (Apr – Jun) seasons (Figure 5, top), suggesting that KSC/MINWR provides important foraging habitat for breeding populations of wading birds. Numbers of foraging wading birds declined during Post-nesting season (Jul – Sep) and were lowest during Winter (Oct – Jan). This period corresponds to seasonally high water levels in the IRL (Provost 1973). In addition to the natural hydrological pattern, management practices at KSC/MINWR during the study period were to maintain high water levels within impoundments during winter months for waterfowl. High fall and winter water levels in impoundments at KSC/MINWR may temporarily reduce the value of these habitats to foraging wading birds (but see habitat Use below).

During these times, shallow habitat along the IRL shoreline and numerous ditches on KSC/MINWR may provide additional alternative habitats for wading birds in fall and winter (Smith and Breining 1995). The seasonal pattern of wading birds observed along the IRL shoreline was opposite the pattern within impoundments, with the mean

Table 3. Results of correlation analysis between mean number individuals / survey and water levels for wading bird foraging surveys in 13 focal impoundments at MINWR. (correlations in bold are significant at $\alpha=0.075$).

Functional Group		mean depth	LAG	LAG2X	LONGLAG
LN(WBTOT)	Pearson Correlation	-0.12	-0.26	-0.11	-0.32
	Sig. (2-tailed)	0.455	0.112	0.519	0.057
	N	38	38	38	37
LN(Piscivores)	Pearson Correlation	-0.26	-0.22	-0.06	-0.23
	Sig. (2-tailed)	0.111	0.185	0.731	0.167
	N	38	38	38	37
LN(Probers)	Pearson Correlation	-0.02	-0.32	-0.14	-0.38
	Sig. (2-tailed)	0.924	0.053	0.417	0.019
	N	38	38	38	37
LN(LBHE)	Pearson Correlation	0.02	-0.08	-0.05	-0.12
	Sig. (2-tailed)	0.884	0.614	0.786	0.497
	N	38	38	38	37
LN(WOST)	Pearson Correlation	-0.19	-0.33	-0.20	-0.46
	Sig. (2-tailed)	0.262	0.046	0.232	0.004
	N	38	38	38	37
LN(ROSP)	Pearson Correlation	-0.38	0.18	0.00	0.15
	Sig. (2-tailed)	0.017	0.283	0.982	0.362
	N	38	38	38	37

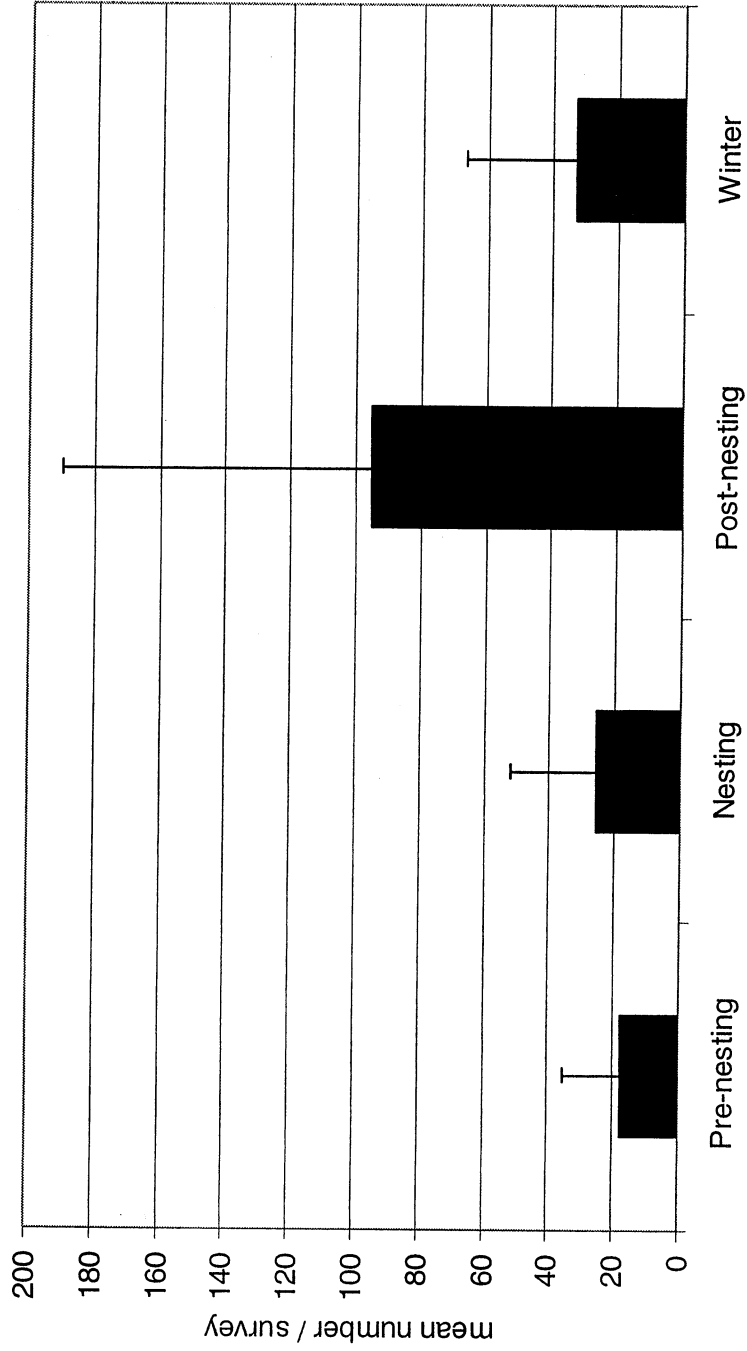
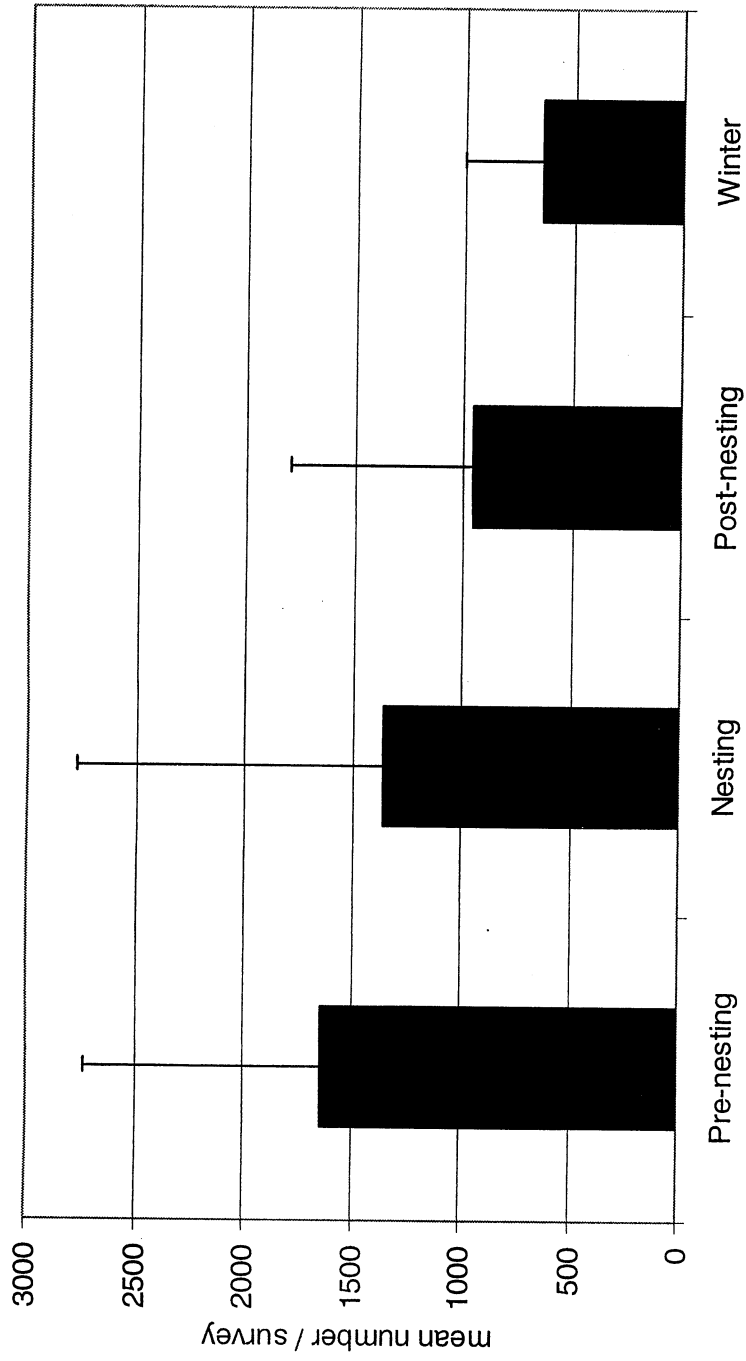


Figure 5. Top, mean number of wading birds / survey observed in 13 focal impoundments by season from April 1987 through September 1998 (error bar gives one standard deviation). Bottom, mean number of wading birds / survey observed along IRL shoreline by season from April 1987 through September 1998 (error bar gives one standard deviation).

number of wading birds / survey observed along the IRL shoreline sections greatest during the Post-nesting season and much lower during the other seasons (Figure 5, Bottom). Wetlands elsewhere in the IRLS and within the adjacent St. John's River basin may provide additional foraging habitat for wading birds during these seasons (Schikorr & Swain 1995).

There was no clear pattern in the yearly mean numbers of wading birds / survey for either the 13 focal impoundments or the IRL shoreline sections (Figure 6). The 11 years of data probably is not sufficient to detect trends in the number of wading birds using KSC/MINWR, given the amount of variation in the data. Some trends apparent within individual species are discussed in Appendix A.

Habitat Use

Wading birds overwhelmingly preferred open water and sparse grass habitat to other available habitat types on KSC/MINWR (Figure 7). Other studies of wading bird use of habitat in Florida have revealed similar preferences (Hoffman et al. 1994, Smith 1995a, 1995b). Wading birds at KSC/MINWR showed a minor shift in use of habitat from open water to other types during winter. This change coincided with an increase in water depth within the impoundments during this season. When impoundments become flooded, prey populations respond by migrating to different parts of the marsh (Gilmore 1995). These seasonal shifts in wading bird habitat use may be an important feature of the foraging strategy some wading bird species. Details of seasonal changes in habitat use by individual species are discussed in Appendix A.

Trends in Numbers Nesting

Little change in the number of wading bird nesting attempts occurred during the years 1978 through 1989, with the exception of an unusually high number of attempts in 1990 (Figure 8, top). White Ibis accounted for over 53% of all wading bird nests counted during the study (Figure 8, bottom). Although not statistically significant, a negative trend is evident in the number of wading bird nests counted per year. Another noteworthy trend was the general decrease in colony size that occurred during the study period. Wading birds nested at 37 different colony sites during the 11 years. Although

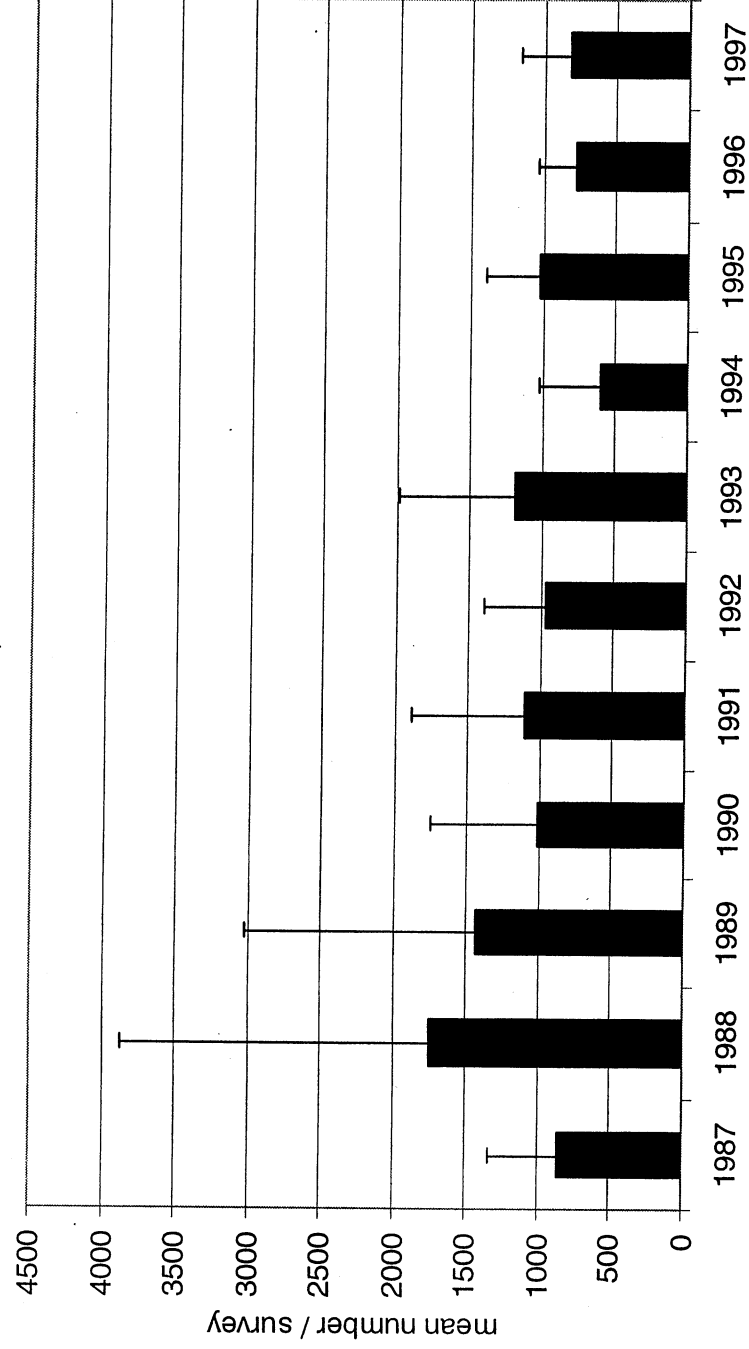
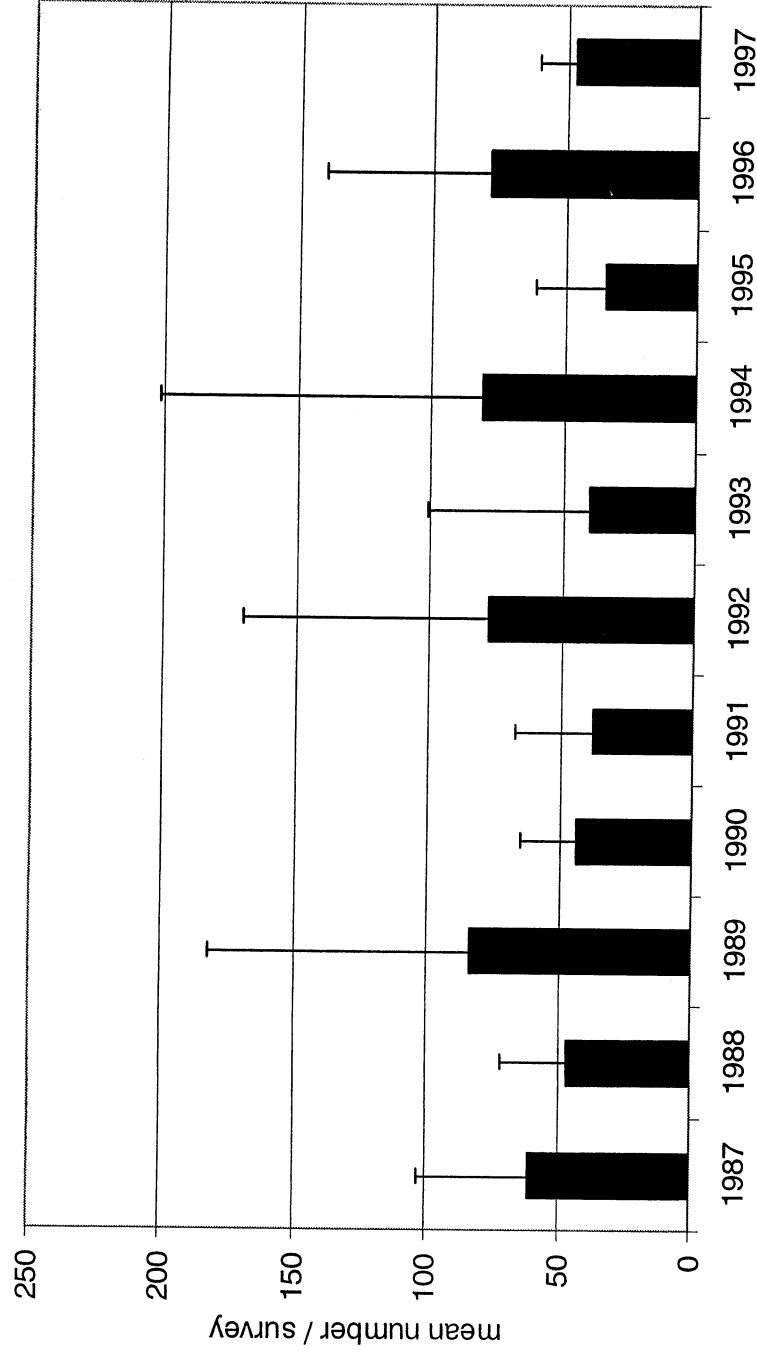


Figure 6. Top, mean number of wading birds / survey observed 13 focal impoundments by year from April 1987 through September 1998 (error bar gives one standard deviation). Bottom, mean number of wading birds / survey observed along IRL shoreline by year from April 1987 through September 1998 (error bar gives one standard deviation).

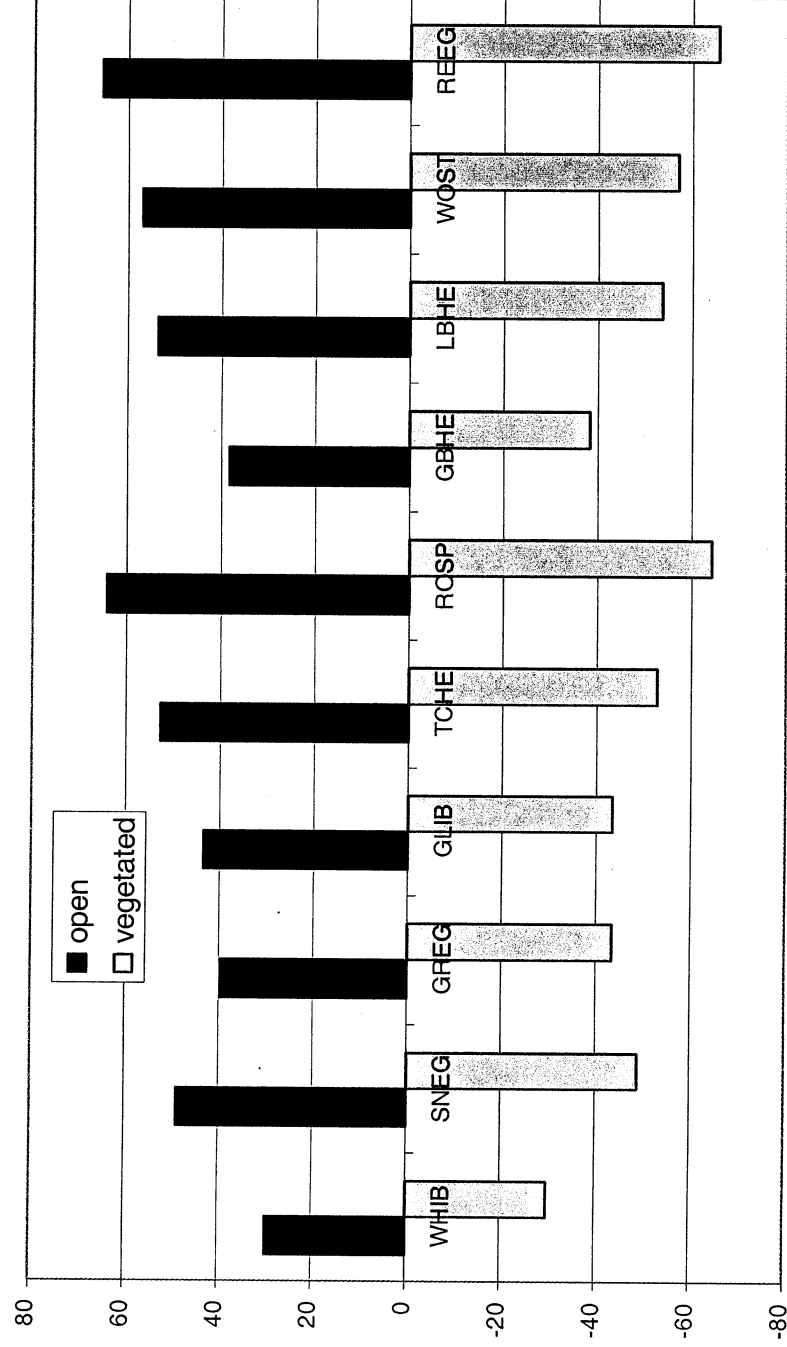
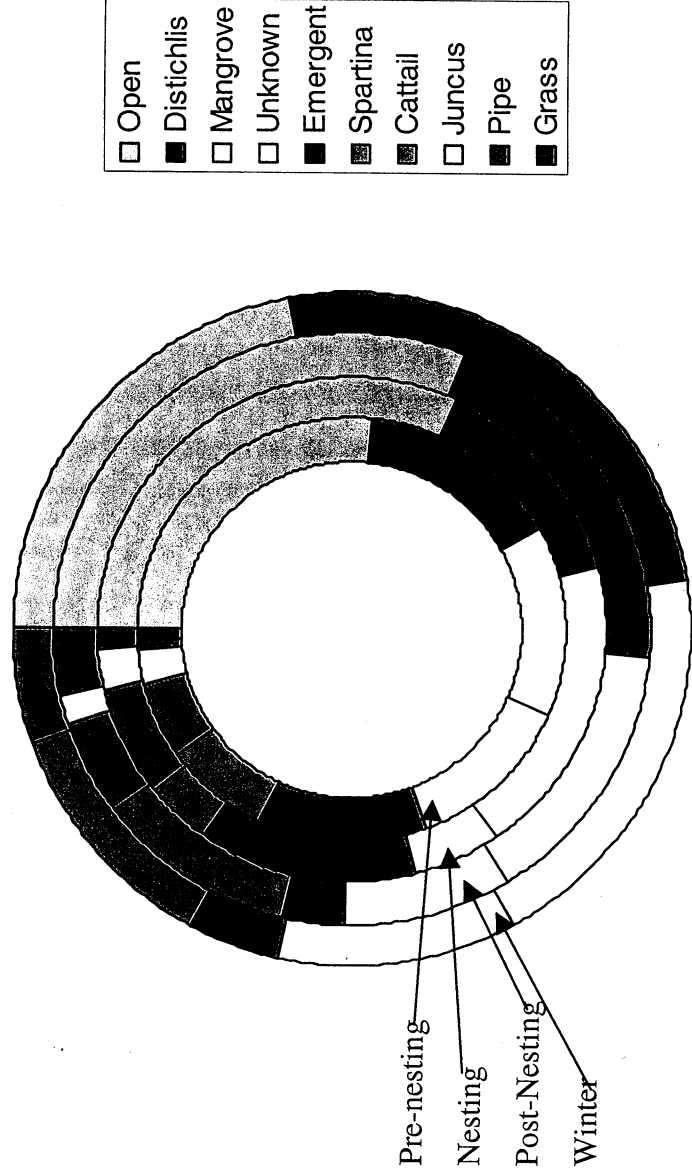


Figure 7. Above, combined seasonal habitat use by all wading birds observed during foraging surveys in thirteen focal impoundments at MINWR from April 1987 through September 1997. Seasons : Pre-nesting (February- March), nesting (April-June), Post-nesting (July-September), winter (October - January). Below, habitat selection for all wading birds observed during foraging surveys in thirteen focal impoundments at MINWR from April 1987 through September 1997. Habitat selection calculated as difference between use and availability of habitat type; vegetated habitat includes all wetland vegetation land cover types, open refers to Open water.

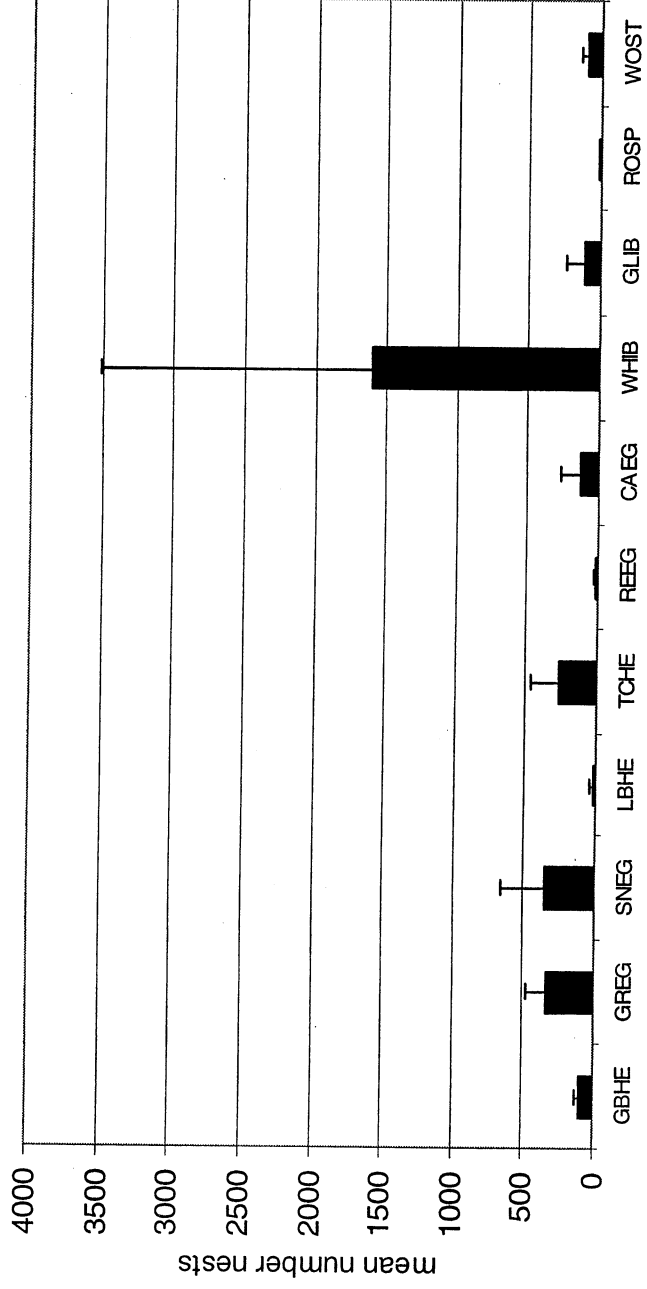
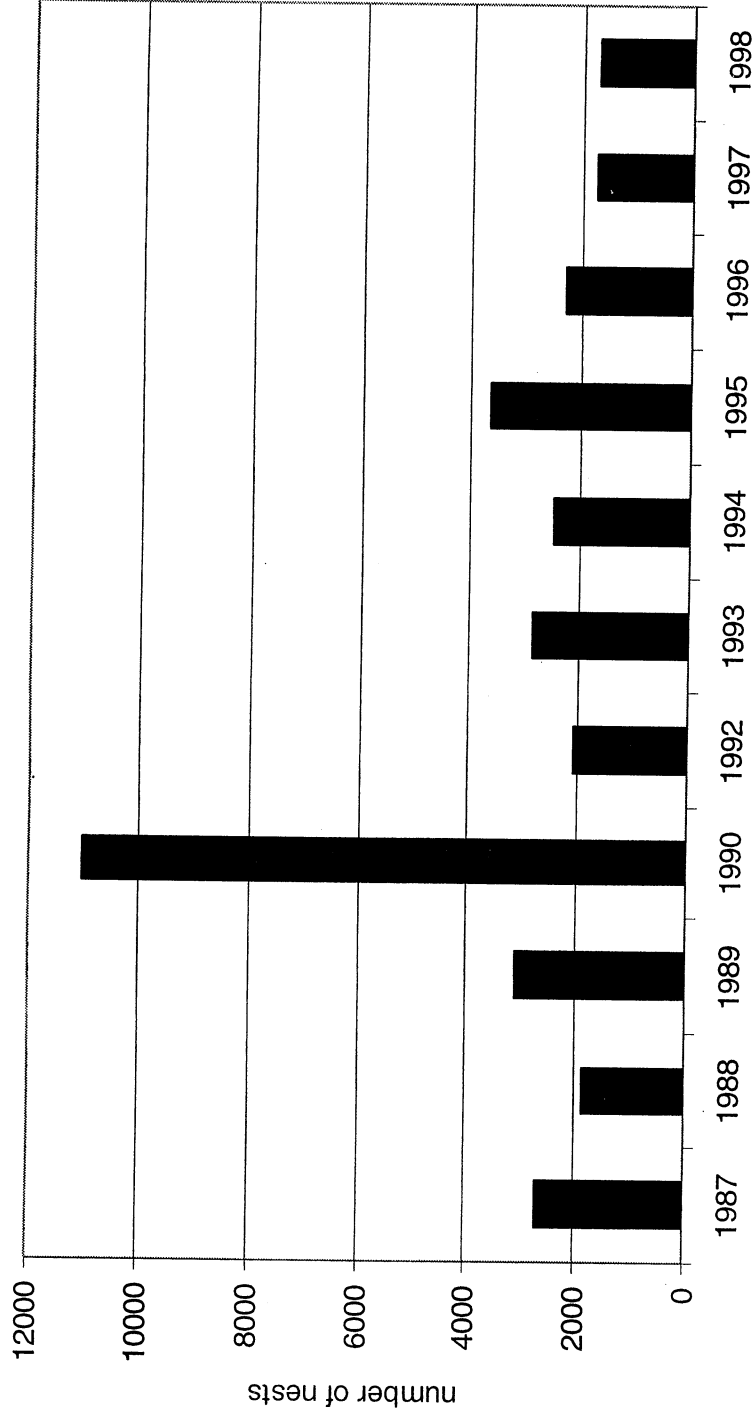


Figure 8. Above, total number of wading bird nests counted during April survey at MINWR from 1987 through 1998. Below, yearly mean number of nests for 11 species of wading birds on MINWR, data from April surveys 1987 through 1998.

the total number of nests appeared fairly stable between years, the mean number of nests per colony decreased throughout the survey (Table 4). This resulted in a significant negative correlation between year and mean number of nests / colony when 1990 was excluded (Pearson $r = -0.783$, $p = 0.007$). A similar pattern was noted for wading bird nesting colonies within Florida between 1976 and 1989 (Runde 1991). Combined with the overall decline in numbers statewide, these trends are alarming and continued monitoring of wading bird nesting colonies on KSC/MINWR is warranted. Details of nesting by individual species will be discussed in Appendix A.

The entire IRLS has been estimated to host roughly 10% of the total of annual nesting attempts by wading birds in Florida (Schikorr & Swain 1995). That portion of the IRLS that is contained solely within the KSC/MINWR boundary makes a substantial contribution to this effort. For example, in 1993 nesting attempts on KSC/MINWR represented 24-30% of the total nesting by wading birds in the IRLS based on numbers reported by Schikorr & Swain (1995). Wetlands in the adjacent St. John's River basin support a similar level of nesting (Schikorr & Swain 1995, Hoffman 1996). However, there are important differences in species composition, with the inland sites hosting a much greater proportion of Cattle Egret. It has been reported elsewhere that coastal wading bird colonies are often more stable than are inland colonies (e.g. Ogden 1994). Thus, rookeries at KSC/MINWR are important both in terms of numerical contribution to recruitment, and regional demographic stability of wading bird populations in central Florida.

Within Species Trends

Figure 9 shows the relative abundance of the ten focal species, based on the overall mean number / survey for each species for the 13 focal impoundments over the entire study period. White Ibis was the most numerous species. The next most abundant species, Snowy Egret, was only about 75% as abundant. Glossy Ibis and Great Egret were the next most abundant, but were less than half as numerous as Snowy Egrets. Tricolored Heron, the next most abundant species, was less than 75% as abundant as were Glossy Ibis and Great Egret. The remaining species were much less commonly observed during foraging surveys with abundances an order of magnitude below the top

Table 4. Summary of wading bird colony size on KSC/MINWR between 1987 and 1998.

Year	Total Nests	Number Colony Sites	Mean Number / Colony
1987	2689	10	268.9
1988	1846	5	369.2
1989	3110	8	388.75
1990	11024	7	1574.857143
1992	1773	7	253.2857143
1993	2852	12	237.6666667
1994	1738	13	133.6923077
1995	2614	9	290.4444444
1996	2042	11	185.6363636
1997	1362	8	170.25
1998	1721	16	107.5625

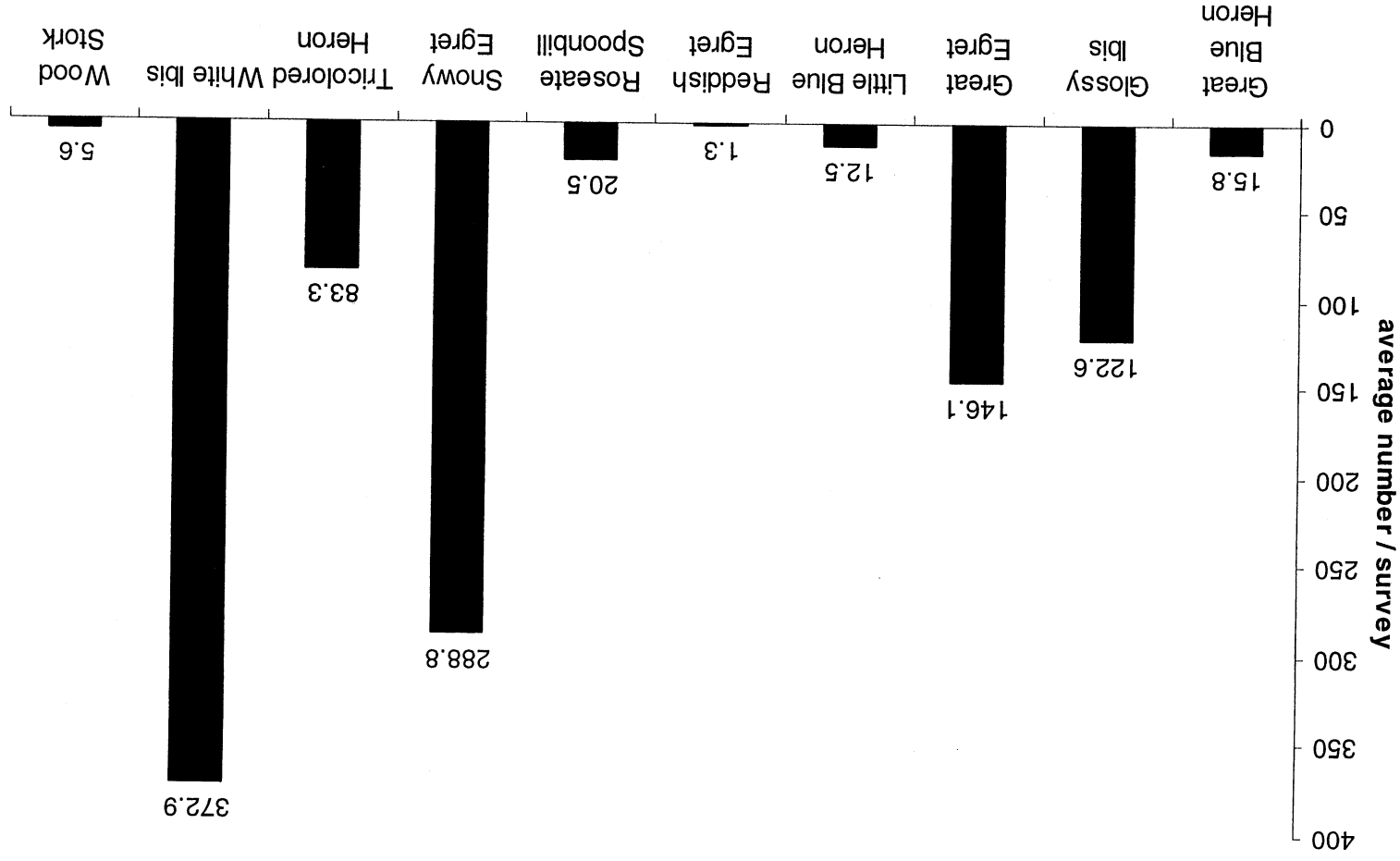


Figure 9. Average number per survey for each of eleven species of wading bird observed during foraging surveys of 13 focal impoundments at MINWR from April 1987 through September 1997.

five species. Appendix A describes specific trends for each species, based on data from the 13 focal impoundments only (i.e. Shiloh 1, Shiloh 3, Shiloh 5, and T24 D excluded).

Recommendations for future monitoring and management

Based on this preliminary analysis of trends in wading bird foraging habitat use and nesting effort, the following management recommendations are suggested:

- 1) Continue systematic monitoring wading bird populations on KSC/MINWR to establish baseline data and detect trends that may warrant future management of habitat.
- 2) Initiate additional monitoring programs for species that show preliminary evidence of declines in numbers of foragers (e.g. White Ibis, Snowy Egret, Glossy Ibis, Tricolored Heron, Little Blue Heron, and Wood Stork) or nesters (e.g. Snowy Egret, Glossy Ibis, Little Blue Heron, and Wood Stork).
- 3) Develop opportunities to generate new types of information on wading bird habitat use and demography, such as habitat selection, location of prey, individual movement patterns, and detailed demographic data. Some potential sources of such information include use of radio telemetry or tagging, monitoring of nesting colonies, and detailed foraging studies.
- 4) Encourage studies that investigate the mechanisms responsible for patterns in wading bird use of foraging and nesting habitat on KSC/MINWR.

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APPENDIX A. Wading Bird Foraging Surveys Results by Species.

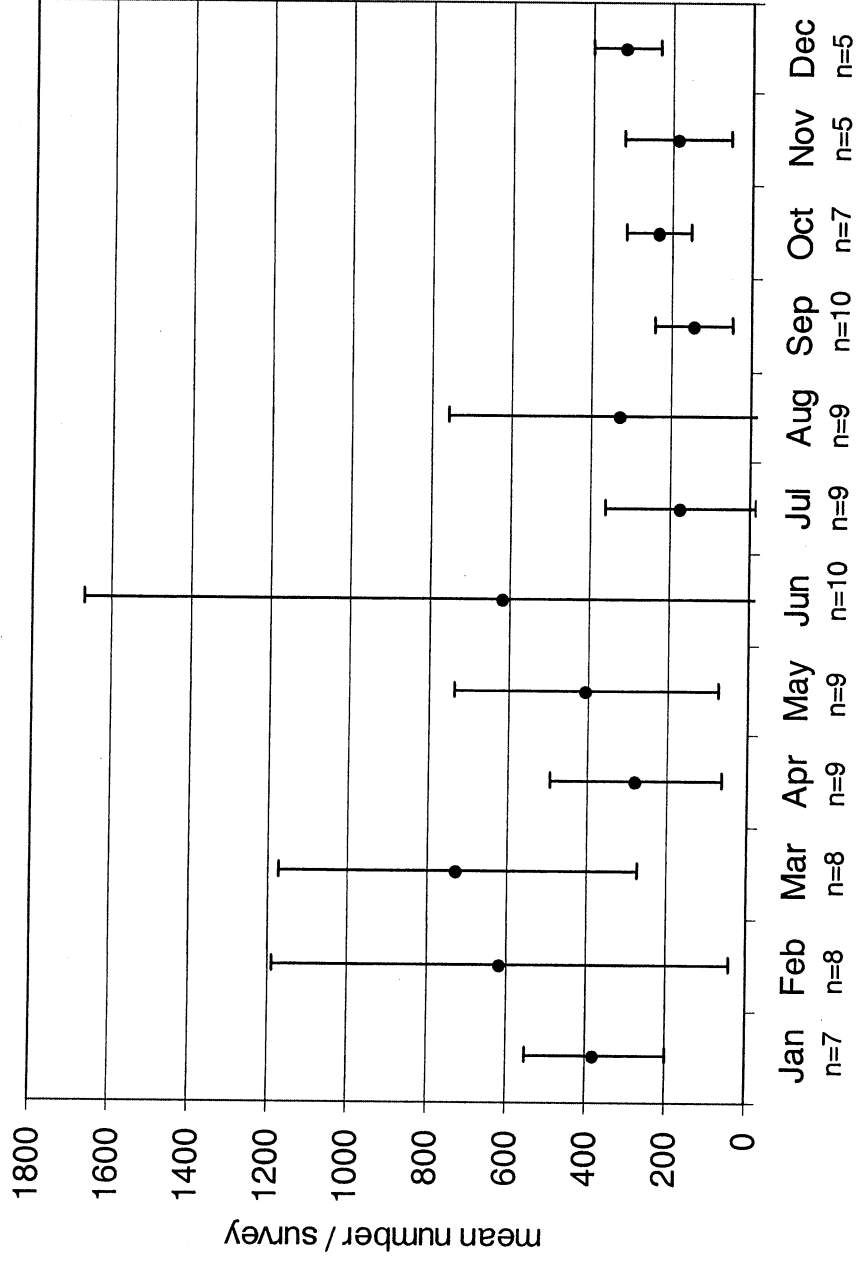
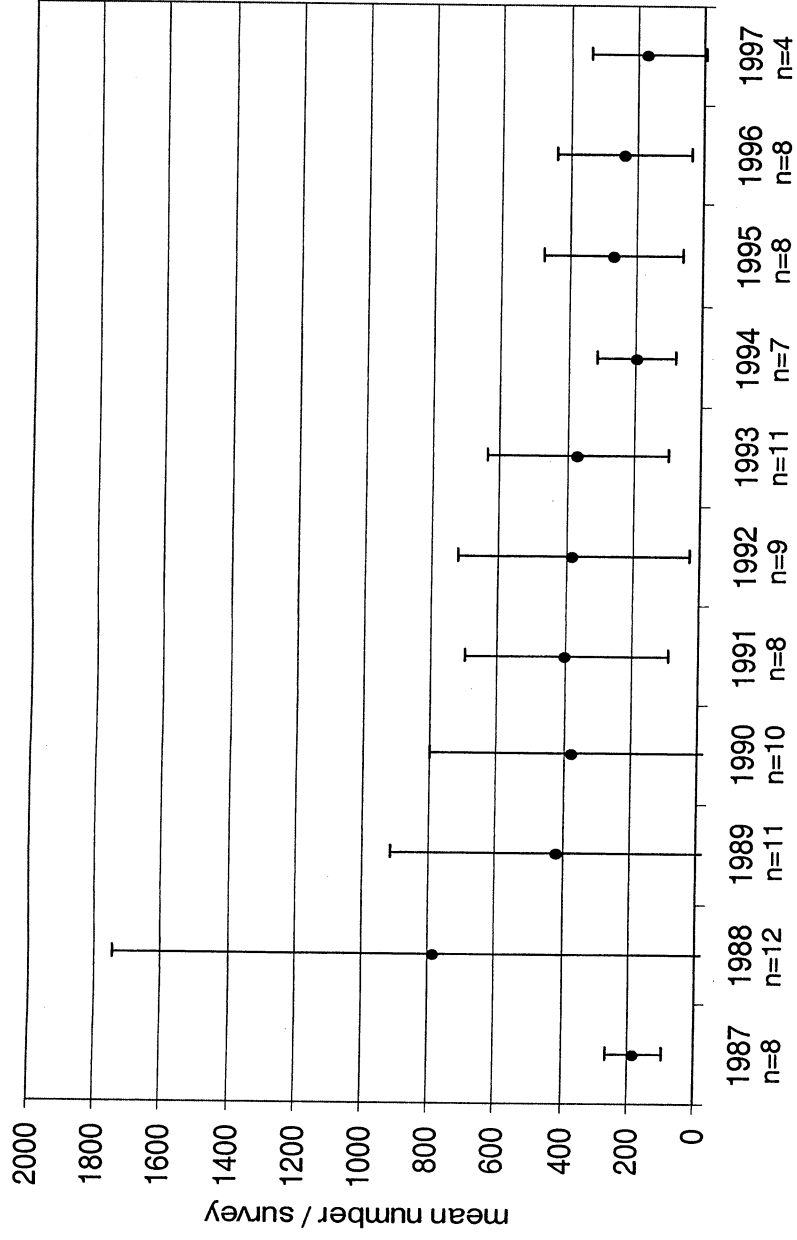
White Ibis – White Ibis were the most abundant species observed nesting and during foraging surveys. White Ibis accounted for slightly more than half of all nests counted, and were roughly 30% more abundant during foraging surveys than the next most abundant species (Snowy Egret). There was no significant trend in the number of White Ibis over the 11 years of foraging surveys, although the numbers were generally higher during the first seven years than the last four. There was evidence that White Ibis were less common during Post-nesting and Winter seasons than during other seasons. This overall pattern was complicated by differing temporal patterns of use within individual impoundments. Seasonal differences in the use of impoundments may reflect the foraging preferences of nesting adults provisioning young. White Ibis have been shown to prefer freshwater wetlands for foraging while provisioning nests. Lower use of impoundments during winter could be related to occurrence of higher water levels during this season; several studies have shown that White Ibis prefer drying marshes to flooded conditions. Except for the exceptionally high numbers nesting in 1990, there was no obvious trend in numbers of White Ibis nesting during the study.

During the foraging surveys, White Ibis were much more abundant in some impoundments than others. Impoundments that stood out as having exceptional abundances of White Ibis were T38, T33A, and T27B. Impoundments T27D and T10L also had high abundances of foraging White Ibis, although not as dramatic. These same five impoundments were also observed to have high abundances of several other species of wading birds. The impoundments that were heavily used by wading birds generally had higher ratios of marsh to open water habitat than those that were less used. Although there appears to be a loose relationship between the ratio of open water to marsh habitat and the use of impoundments on KSC/MINWR by wading birds, more information on the causal mechanisms behind wading bird habitat preference is needed.

Although not statistically significant, trends within individual impoundments were evident with some impoundments showing declines and others having moderate increases in numbers during the study period. These trends may reflect habitat changes within impoundments such as changes in the relative amount of cattail and open water. For instance, numbers declined sharply in impoundment C2136 during the study period, while the amount of cattail within this impoundment increased at the expense of open

water habitat during this period.

White Ibis preferred Open Water habitat during most of the year, but preference shifted sharply to Distichlis during July and late Fall through Winter, when the use of Mangrove habitat also increased. The shift in July corresponds to a sharp decline in numbers from the previous month, and may be correlated with patterns of rainfall or perhaps changes in foraging behavior related to nesting activity. The shift during Fall and Winter was also associated with lower numbers, and probably reflects a response to increased water levels on impoundments during this time period. White Ibis continued to use Distichlis and Mangrove habitat through the spring dry-down period, perhaps taking advantage of drying in marshes that made invertebrate prey more available. These seasonal changes in habitat use by White Ibis reflect the importance of changing water levels to foraging habitat, and stress the importance of management strategies that make a variety of habitat types available throughout the year.



Monthly and Yearly trends in average number of White Ibis observed during foraging surveys at Merritt Island National Wildlife Refuge between April 1987 and September 1997. Points mark mean number per survey and bars give one standard deviation around mean.

Snowy Egret - Snowy Egret were the second most abundant species observed nesting and during foraging surveys. Snowy Egret accounted for around 12% of all nests counted, and were roughly twice as abundant during foraging surveys than the next most abundant species (Great Egret). There was no significant trend in the number of Snowy Egret over the 11 years of foraging surveys. However, yearly trends within Season were evident for this species. A decline over the eleven years evident within Nesting season and perhaps also in Winter warrants concern and continued monitoring for this species. If further evidence of a decline is detected, investigation into the causal mechanisms should be initiated.

During the foraging surveys, Snowy Egret were much more abundant in some impoundments than others. Impoundments that stood out as having exceptional abundances of White Ibis were T33A, T38, T27B, and T27D, and to a lesser extent, T10L. These same impoundments were also observed to have high abundances of several other species of wading birds. As noted above for White Ibis, the impoundments that were heavily used by wading birds generally had higher ratios of marsh to open water habitat than those that were less used. Although not statistically significant, trends within individual impoundments were evident with some impoundments showing declines and others having moderate increases in numbers during the study period. These trends may reflect habitat changes within impoundments.

Snowy Egret preferred Open Water habitat during most of the year, but preference shifted sharply towards Distichlis during Fall. This shift was associated with a sharp decline in numbers, and may reflect a response to increasing water levels on impoundments during this time period. Snowy Egret use of Distichlis declined during Winter, and was very low by the spring dry-down period. This seasonal change in habitat use by Snowy Egret reflects the importance of changing water levels to their use of foraging habitat. Management strategies that make a variety of habitat types available throughout the year may be beneficial to this species.

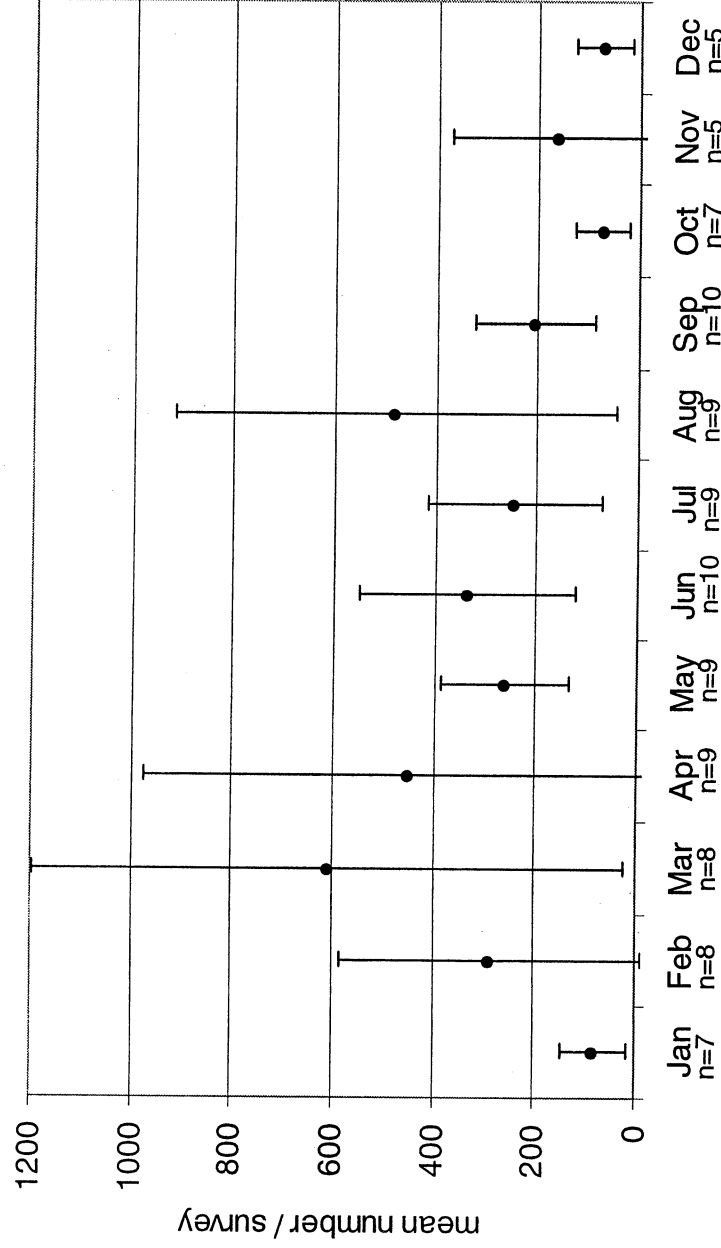
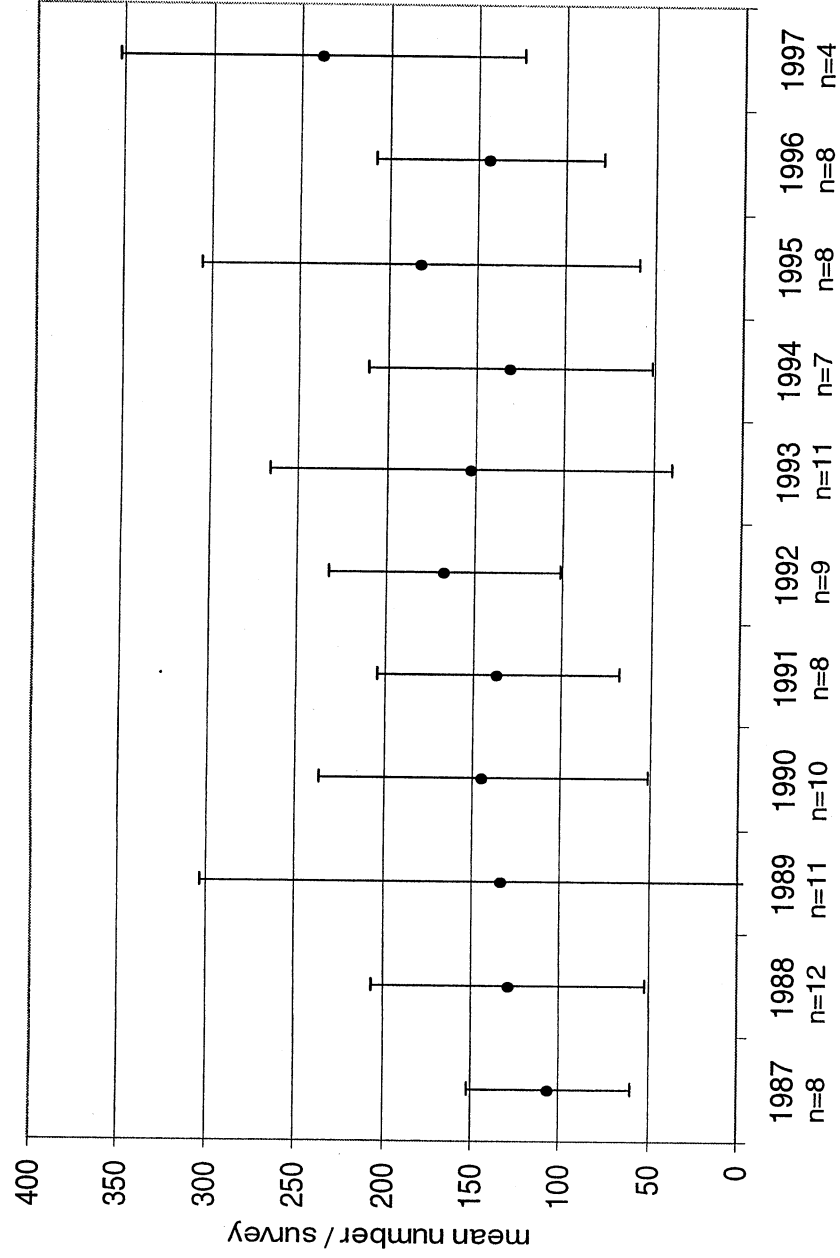
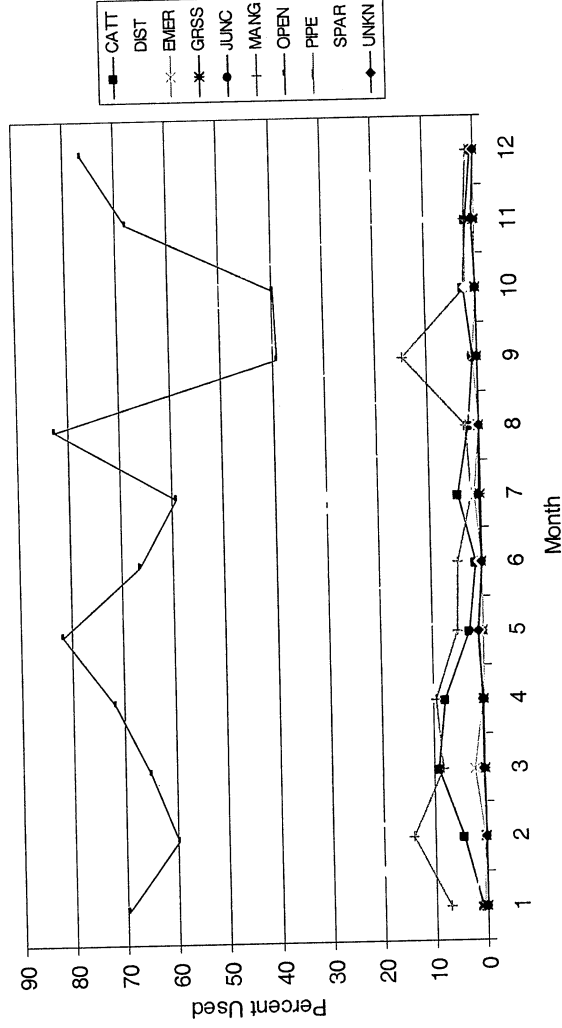
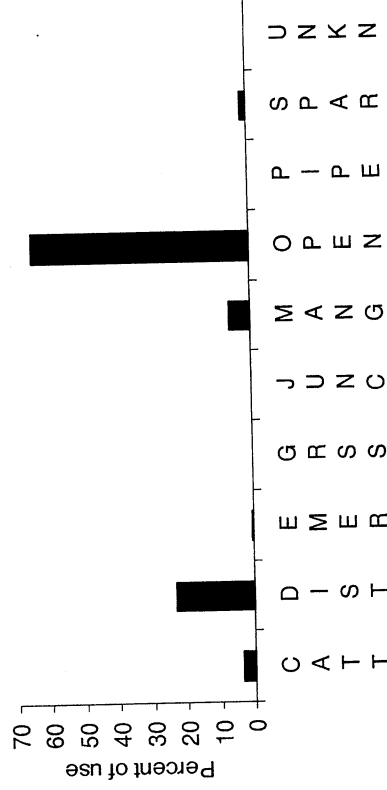
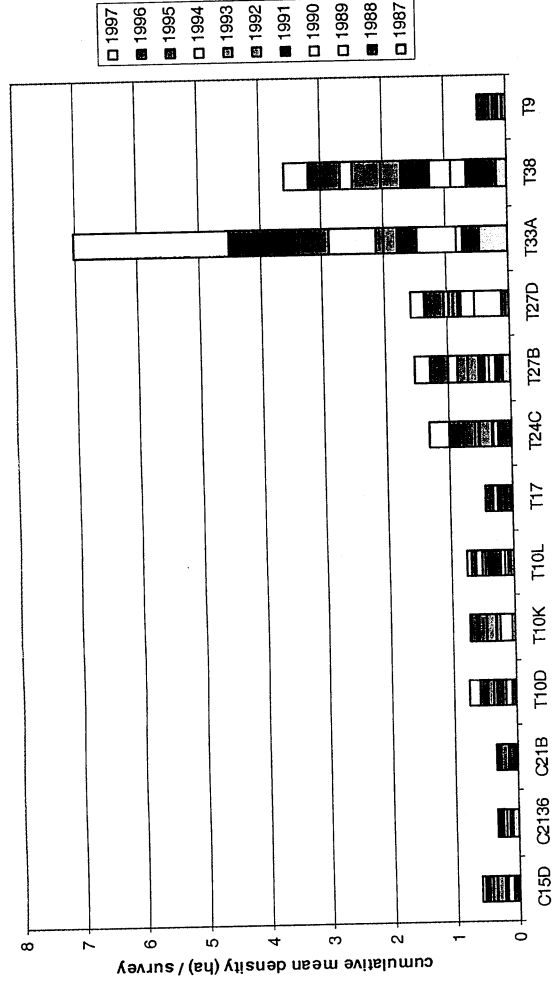


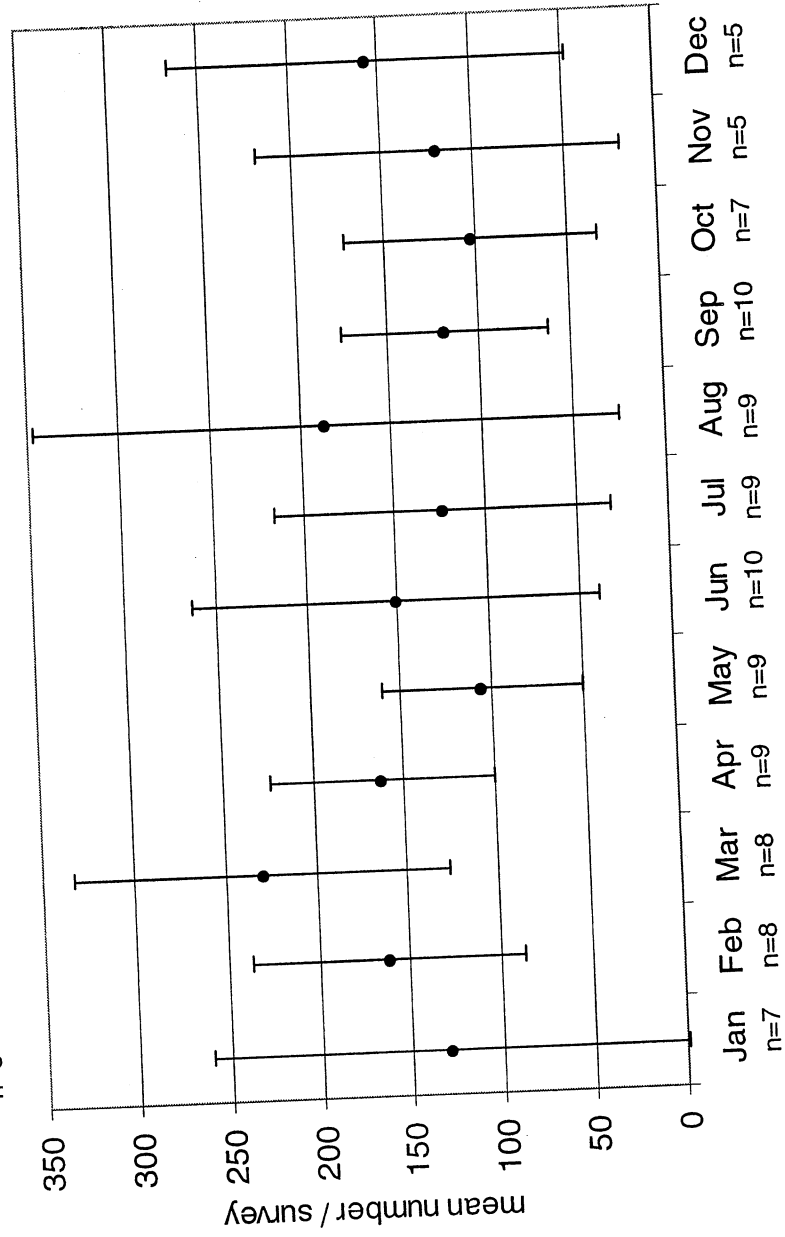
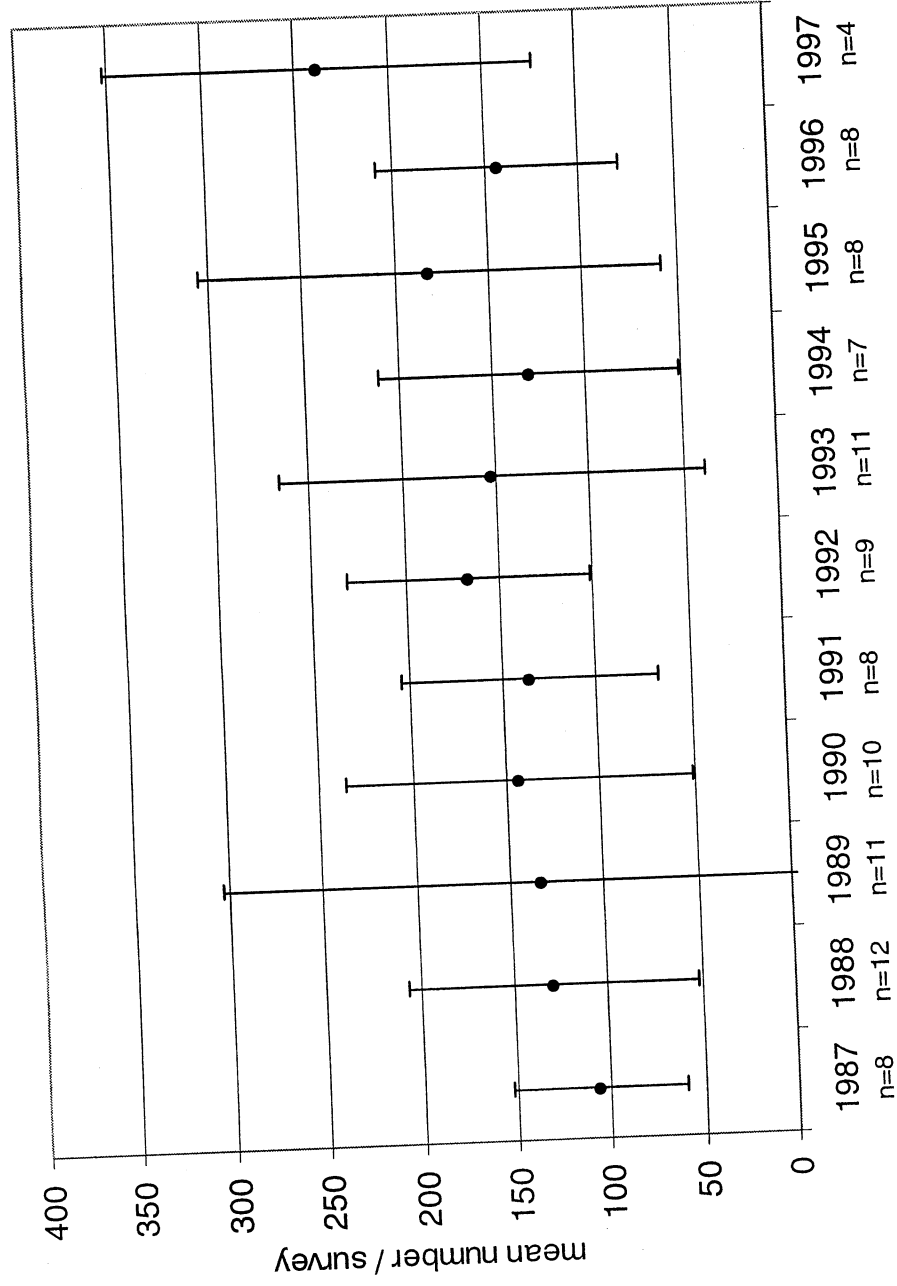
Figure 22. Monthly and Yearly trends in average number of Snowy Egret observed during foraging surveys at Merritt Island National Wildlife Refuge between April 1987 and September 1997. Points mark mean number per survey and bars give one standard deviation around mean.

Great Egret - Great Egret were the third most abundant species observed nesting and during foraging surveys. Great Egret accounted for around 11% of all nests counted, and while still abundant, were only 2/5 to 1/2 as numerous during foraging surveys as were White Ibis or Snowy Egret (respectively). There was no significant trend in the number of Great Egret over the 11 years of foraging surveys. During the foraging surveys, Great Egret were much more abundant in some impoundments than others. Impoundments that stood out as having exceptional abundances of Great Egret were T33A and T38, and to a lesser extent, T27B, T27D, and T10L. These same impoundments were also observed to have high abundances of several other species of wading birds. However, these trends are less pronounced when only density is considered; by density only impoundments T33A and T38 stand out as having high Great Egret use. In general, Great Egrets tended to be more evenly distributed between impoundments; this may reflect their ability to utilize a wider range of water depths and habitat types when foraging.

Great Egret preferred Open Water habitat during most of the year, but preference shifted towards use of Distichlis during Fall. This shift coincided with a slight decrease in numbers of great Egret observed during foraging surveys. Great Egret use of foraging habitat might not be expected to be as influenced by changes in water level as are the shorter legged species. Thus the shift in habitat use by this species may indicate a shift to a more favorable foraging habitat rather than a forced use of habitat due to water depth.



Trends in numbers of Great Egret observed during wading bird foraging surveys in thirteen impoundments at MINWR from April 1987 through September 1997. Above, cumulative average density per survey. Middle, pattern of habitat use. Below monthly proportional habitat use.



Monthly and Yearly trends in average number of Great Egret observed during foraging surveys at Merritt Island National Wildlife Refuge between April 1987 and September 1997. Points mark mean number per survey and bars give one standard deviation around mean.

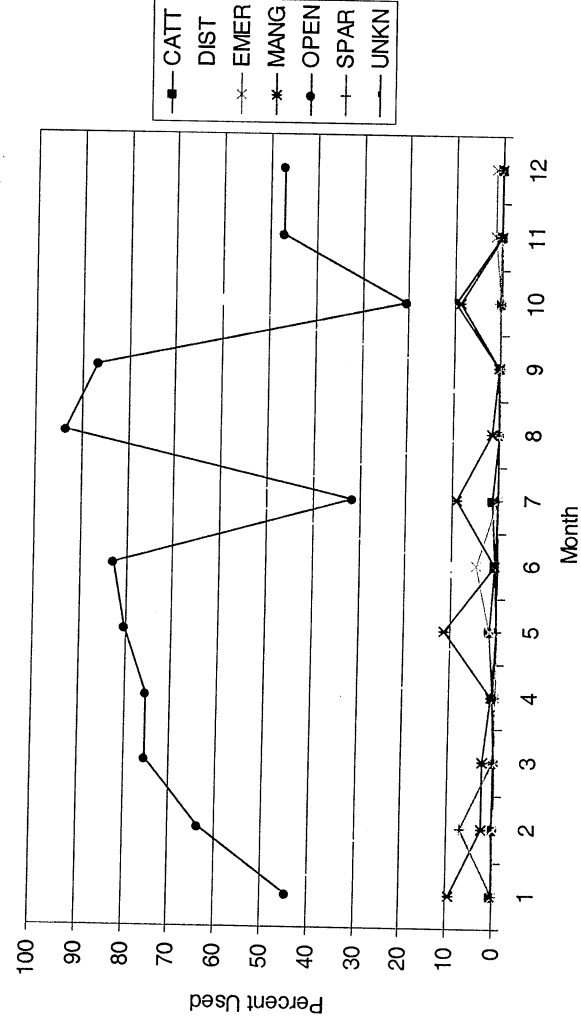
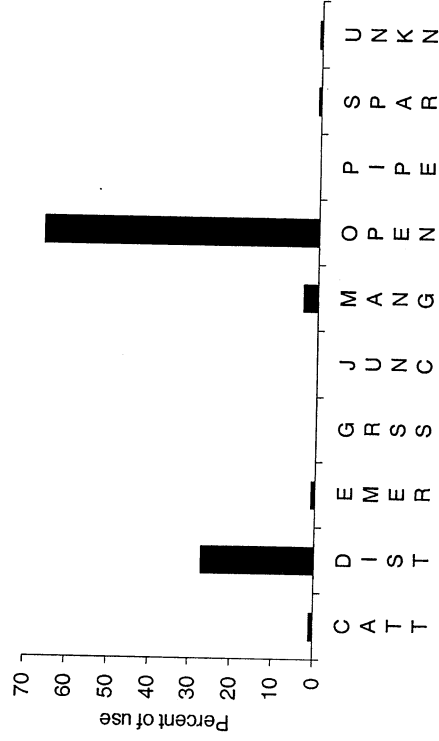
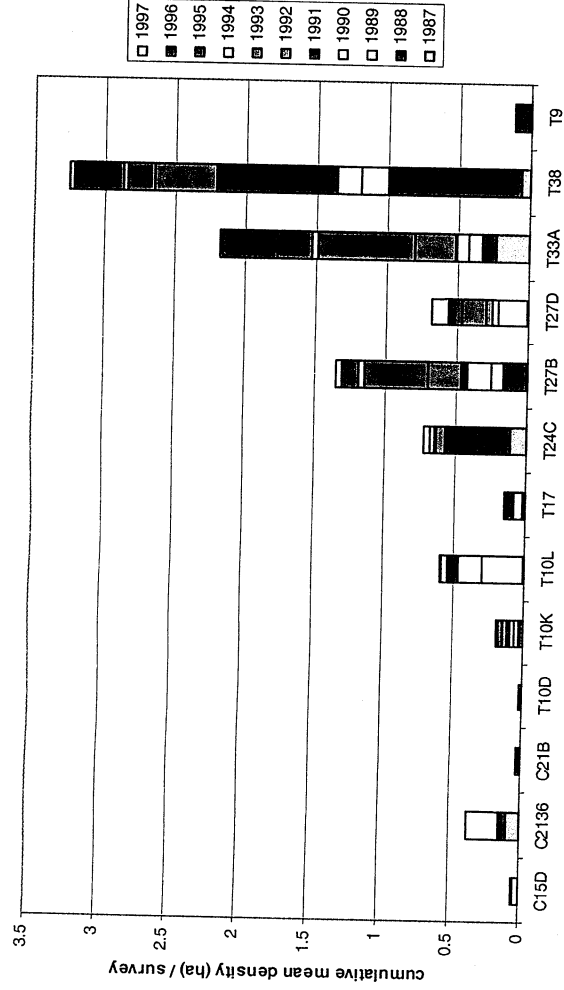
Glossy Ibis - Glossy Ibis were the fourth most abundant species observed during foraging surveys, and were about as abundant as Great Egret. Although there was no significant trend in the number of Glossy Ibis over the 11 years of foraging surveys, a drastic decline in numbers between 1993 and 1994 was evident. Based on the maximum counts of Glossy Ibis per season, numbers may have begun to recover since then, but this trend was not reflected in the mean monthly counts. Glossy Ibis were the sixth most abundant nesting species, accounting for less than 4% of all nests counted. The numbers of nesting Glossy Ibis also dropped precipitously between 1993 and 1994 and remained low throughout the remaining years except for 1996. The evidence for a decline in numbers of foraging and nesting Glossy Ibis warrants concern and continued monitoring of this species. If further evidence of a decline is detected, investigation into the causal mechanisms should be initiated.

During the foraging surveys, Glossy Ibis were much more abundant in some impoundments than others. Impoundments that stood out as having exceptional abundances of Glossy Ibis were T38 and T33A, and to a lesser extent, T27B, T10L, and T27D. These same impoundments were also observed to have high abundances of several other species of wading birds. There was evidence that the changes between years in numbers of foraging Glossy Ibis differed between impoundments. Several impoundments (e.g. T27B, T10K, T10L, T33A, T27D, T38) showed widely varying numbers over the eleven years, but all showed evidence of a decline occurring sometime between 1992 through 1994 with numbers recovering after that. The remaining impoundments showed little change in number of foraging Glossy Ibis over the eleven years.

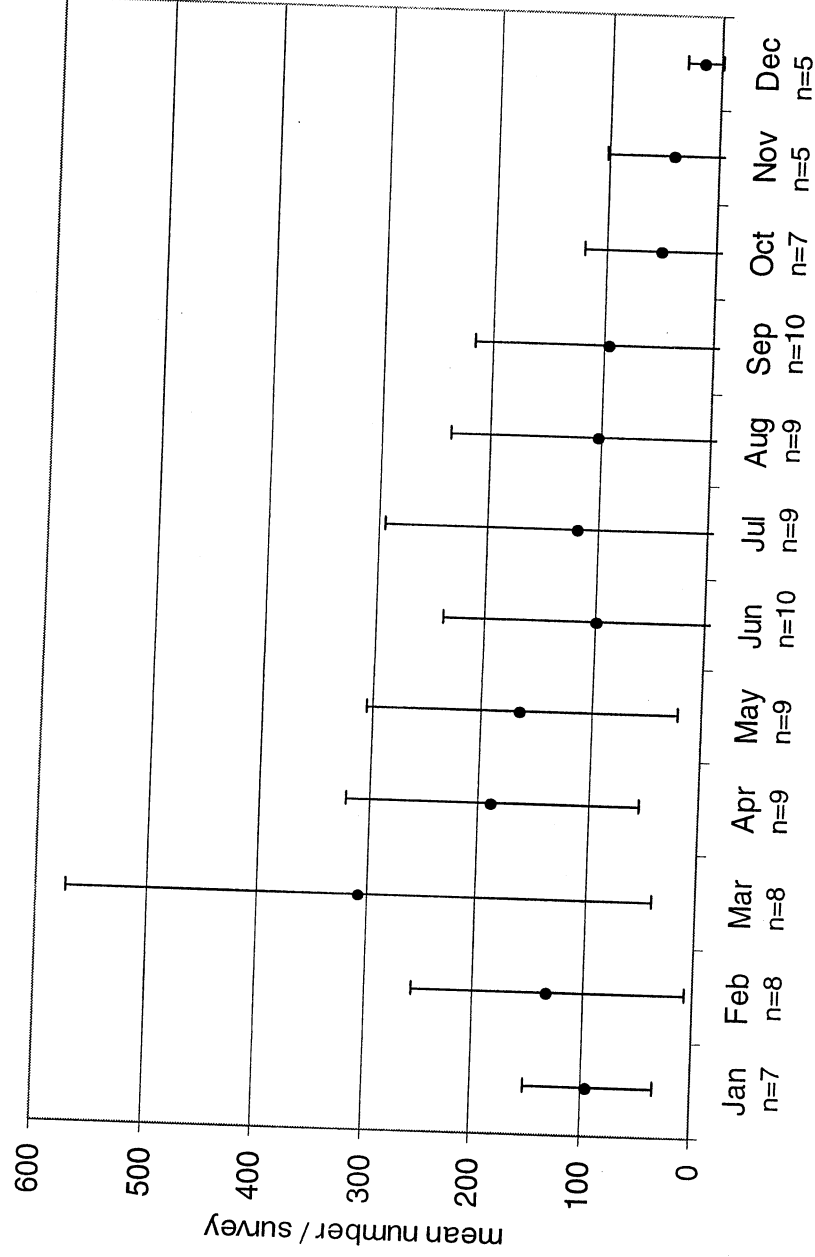
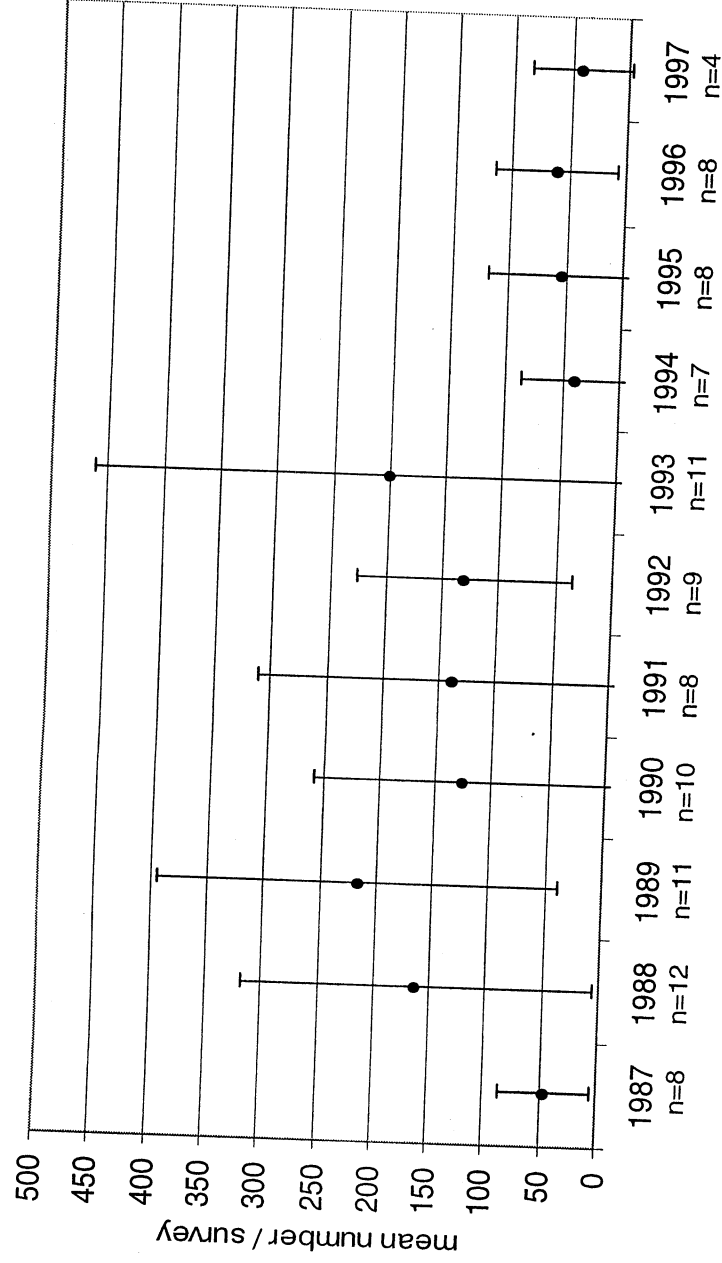
Although not statistically significant, Glossy Ibis were less abundant during Winter than during other seasons. There was evidence of seasonal trends within some impoundments. Impoundments T10L and T27B showed highest numbers during Pre-nesting season; T33A had much fewer foraging Glossy Ibis during Post-nesting season.

Glossy Ibis preferred Open Water habitat during much of the year, but preference shifted sharply to Distichlis during July and late Fall through Winter. The shift in July is similar to that observed for White Ibis (see above) but for Glossy Ibis this change was not associated with a decline in numbers from the previous month. This shift may be

correlated with patterns of rainfall or perhaps changes in foraging behavior related to nesting activity. The shift during Fall and Winter was associated with lower numbers of Glossy Ibis occurring on KSC/MINWR, and may reflect a response to increased water levels on impoundments during this time period. Glossy Ibis continued to use Distichlis habitat through the spring dry-down period, perhaps taking advantage of drying in marshes that made invertebrate prey available. Seasonal changes in Glossy Ibis habitat use reflects the importance of changing water levels to foraging habitat, and stresses the importance of management strategies that make a variety of habitat types available throughout the year.



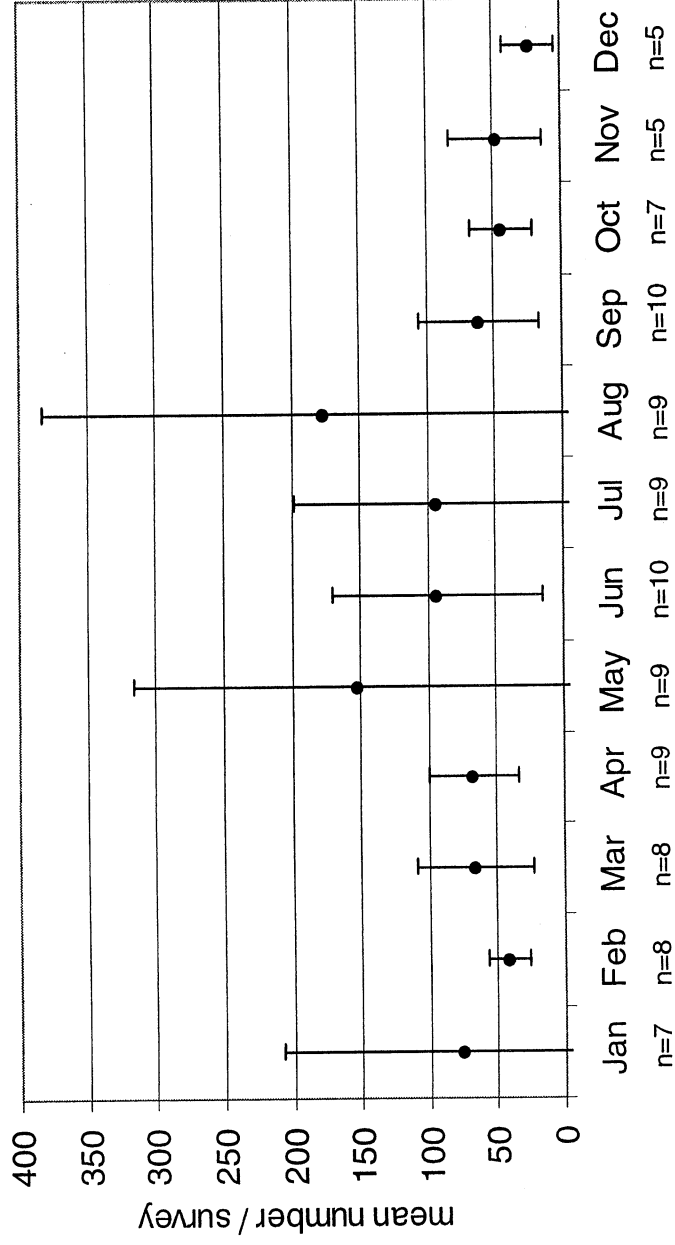
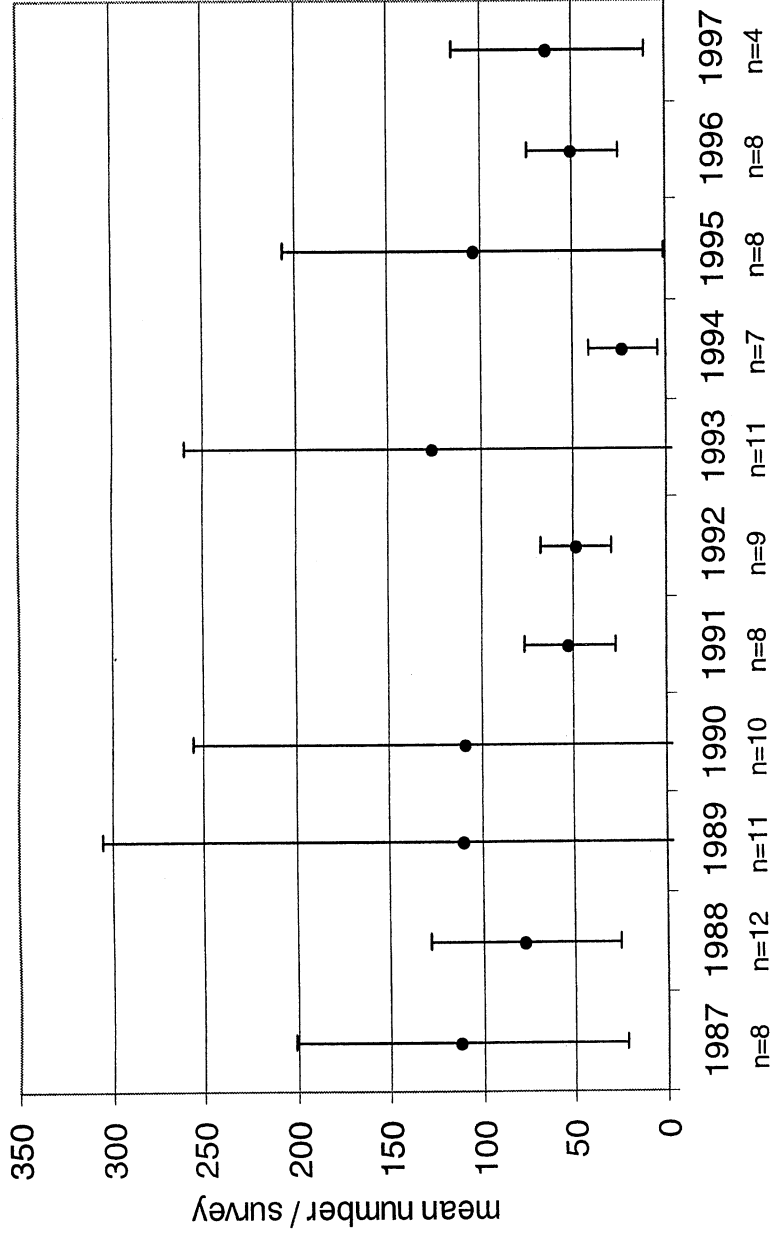
Trends in numbers of Glossy Ibis observed during wading bird foraging surveys in thirteen impoundments at MINWR from April 1987 through September 1997. Above, cumulative average density per survey. Middle, pattern of habitat use. Below monthly proportional habitat use.



Monthly and Yearly trends in average number of Glossy Ibis observed during foraging surveys at Merritt Island National Wildlife Refuge between April 1987 and September 1997. Points mark mean number per survey and bars give one standard deviation around mean.

Tricolored Heron - Tricolored Heron was the fifth most abundant species observed during foraging surveys, roughly 70% as abundant as Glossy Ibis and 57% as abundant as Great Egret. Although in some years significantly more Tricolored Herons were observed during foraging surveys than in other years, there was no clear pattern in the yearly trend in abundance of Tricolored Heron. There was evidence that there were seasonal differences in the abundance of Tricolored Heron between years. However, the within season yearly trends also lacked clear patterns over the eleven-year study period, with wide differences between some years. Within PRE-NESTING and POST-NESTING seasons the numbers appear to decline slightly during the eleven-year study period. There were also large differences in the numbers of Tricolored Heron nests between years, but the trends in numbers of nests were not congruent with the trends in numbers observed foraging.

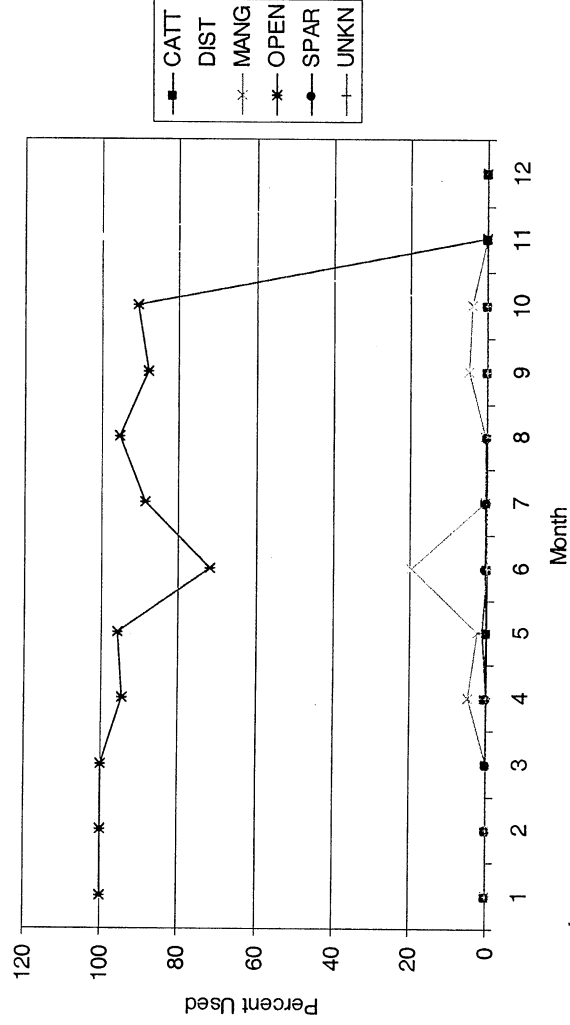
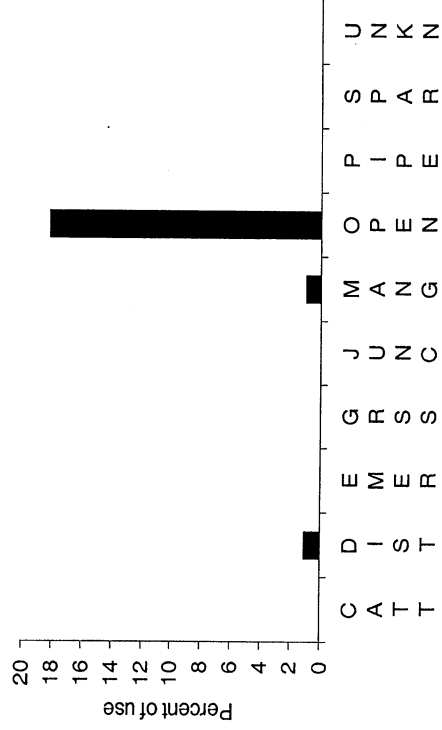
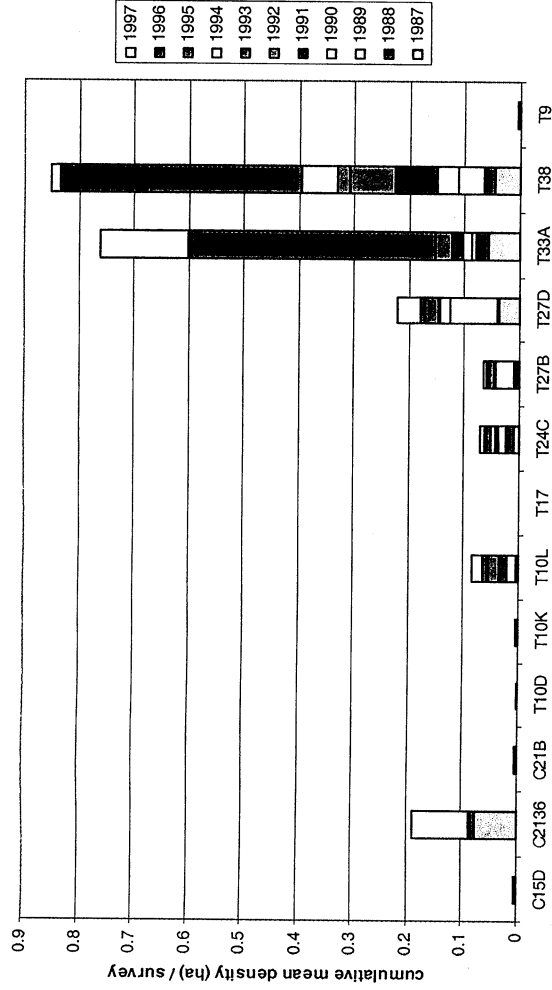
During the foraging surveys, Tricolored Heron were much more abundant in some impoundments than others. Impoundments that stood out as having exceptional abundances of Tricolored Heron were T33A, T38, and T27D, and to a lesser extent, T10L and T27B. These same impoundments were also observed to have high abundances of several other species of wading birds.



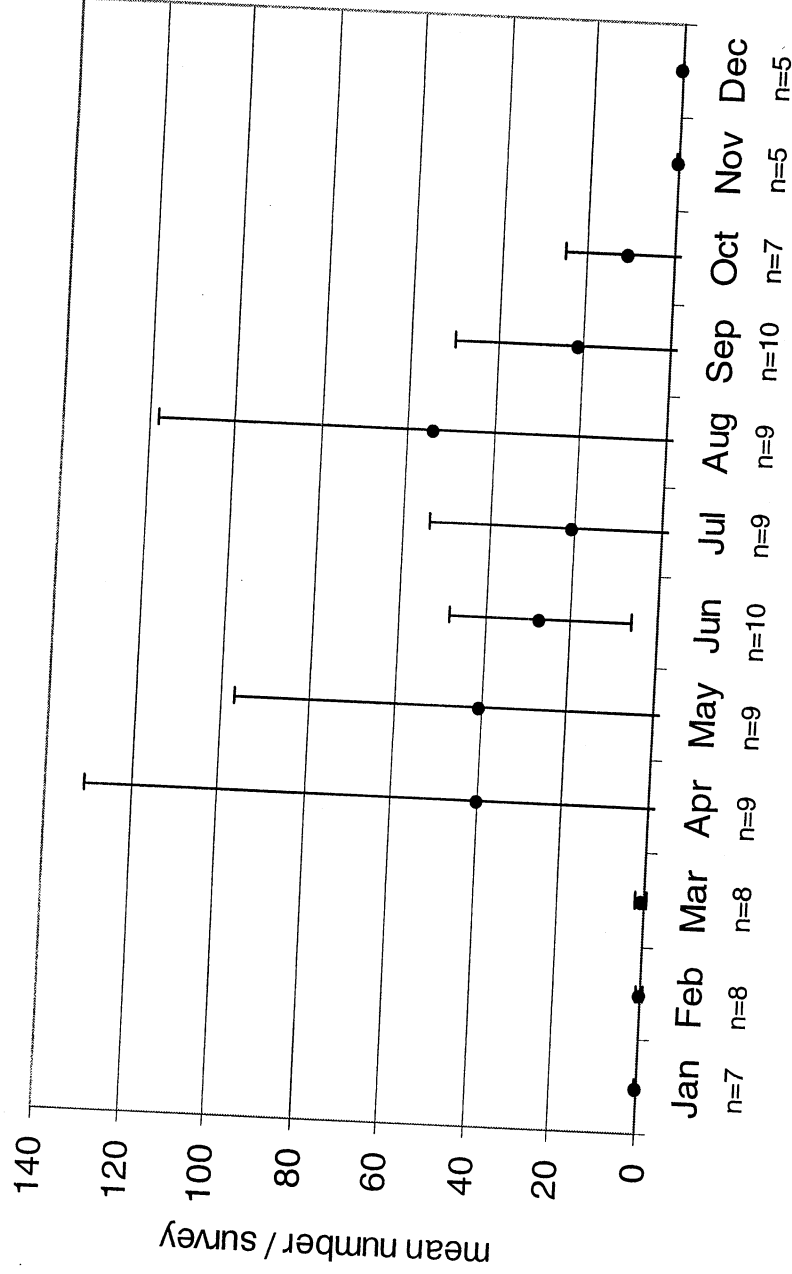
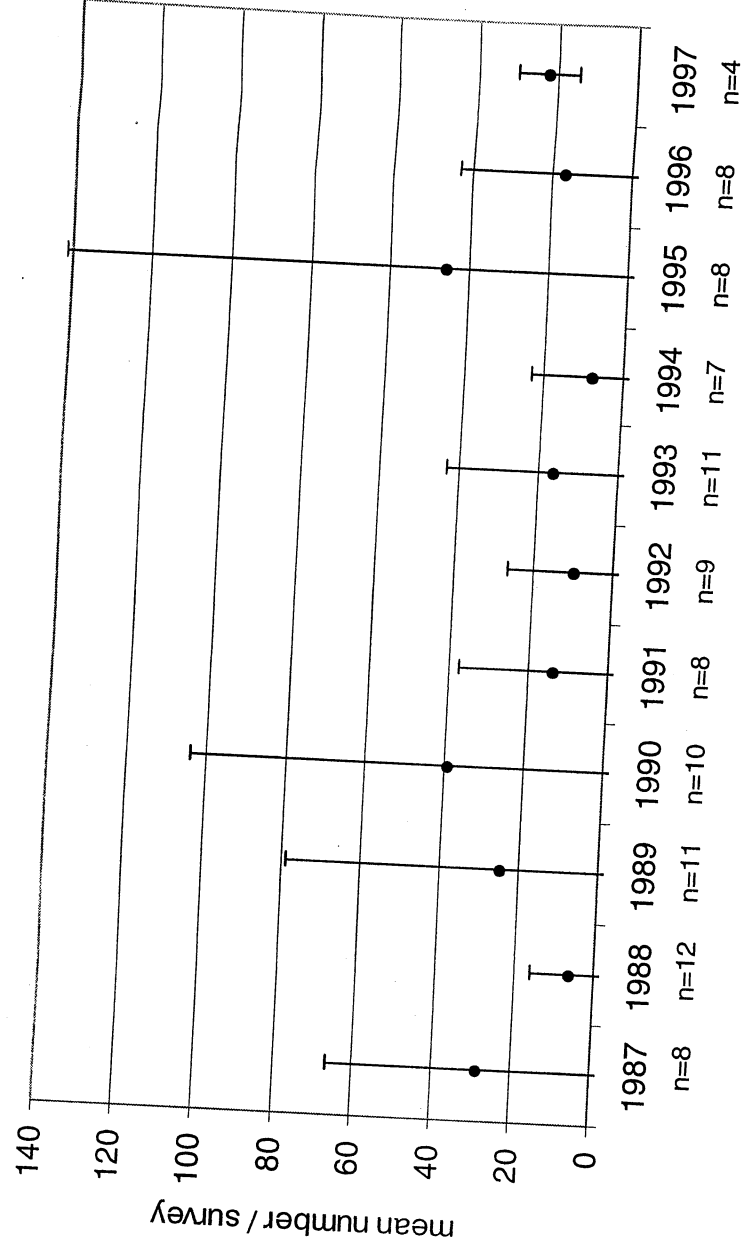
Monthly and Yearly trends in average number of Tricolored Heron observed during foraging surveys at Merritt Island National Wildlife Refuge between April 1987 and September 1997. Points mark mean number per survey and bars give one standard deviation around mean.

Roseate Spoonbill - Roseate Spoonbill was the sixth most abundant species observed during foraging surveys, but was much less abundant than the next most abundant species (Tricolored Heron). Although Roseate Spoonbill were significantly more abundant in some years than in others, there was no clear trend in the yearly abundance during the eleven years of foraging surveys. Difference between the years was most pronounced within the Post-nesting season. Notable is the almost complete absence of Roseate Spoonbill in Fall and Winter. The Roseate Spoonbill is a tropical species and the northern limit of its breeding range on the east coast occurs on KSC/MINWR. Interestingly, despite their occurrence on the refuge exclusively during the breeding season, only a few Roseate Spoonbill nests were found each year.

During the foraging surveys, Roseate Spoonbills were much more abundant in some impoundments than others. Impoundments that stood out as having exceptional abundances of Tricolored Heron were T38, T33A, T10L, T27B, and T27D. These same impoundments were also observed to have high abundances of several other species of wading birds. Roseate Spoonbills were observed primarily foraging in Open habitat within impoundments, with little evidence for extensive use of any of the other habitat types found there.



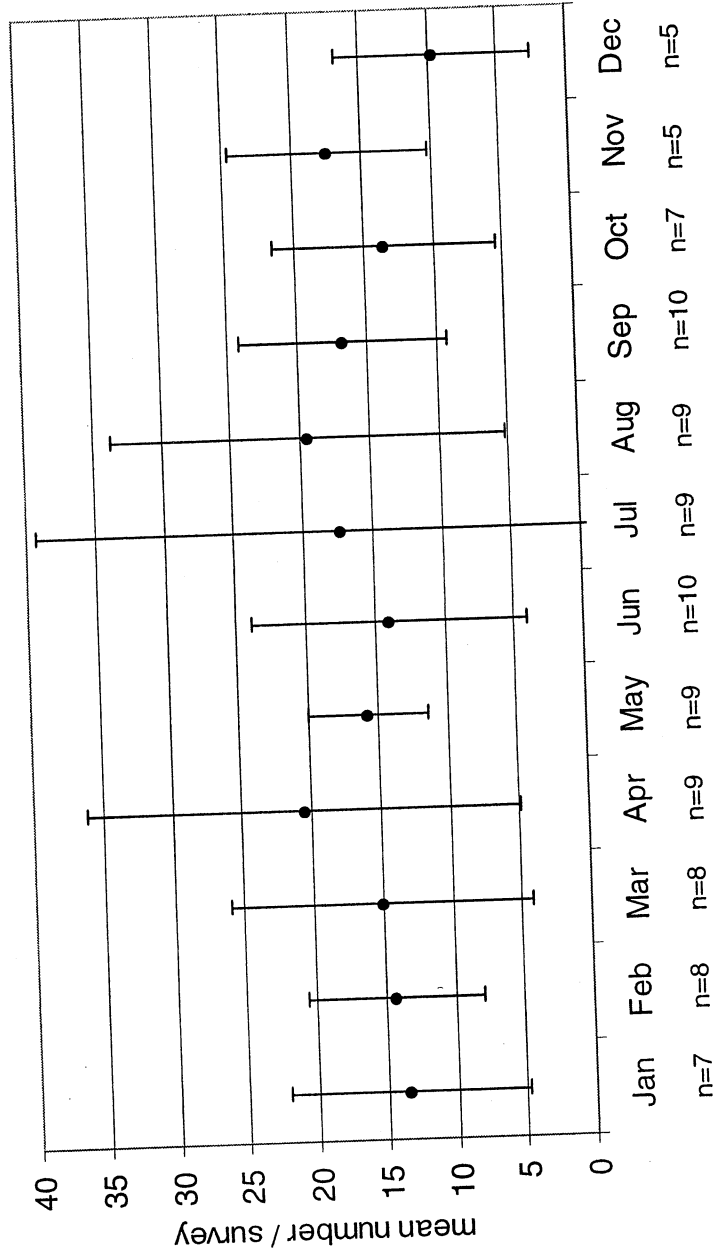
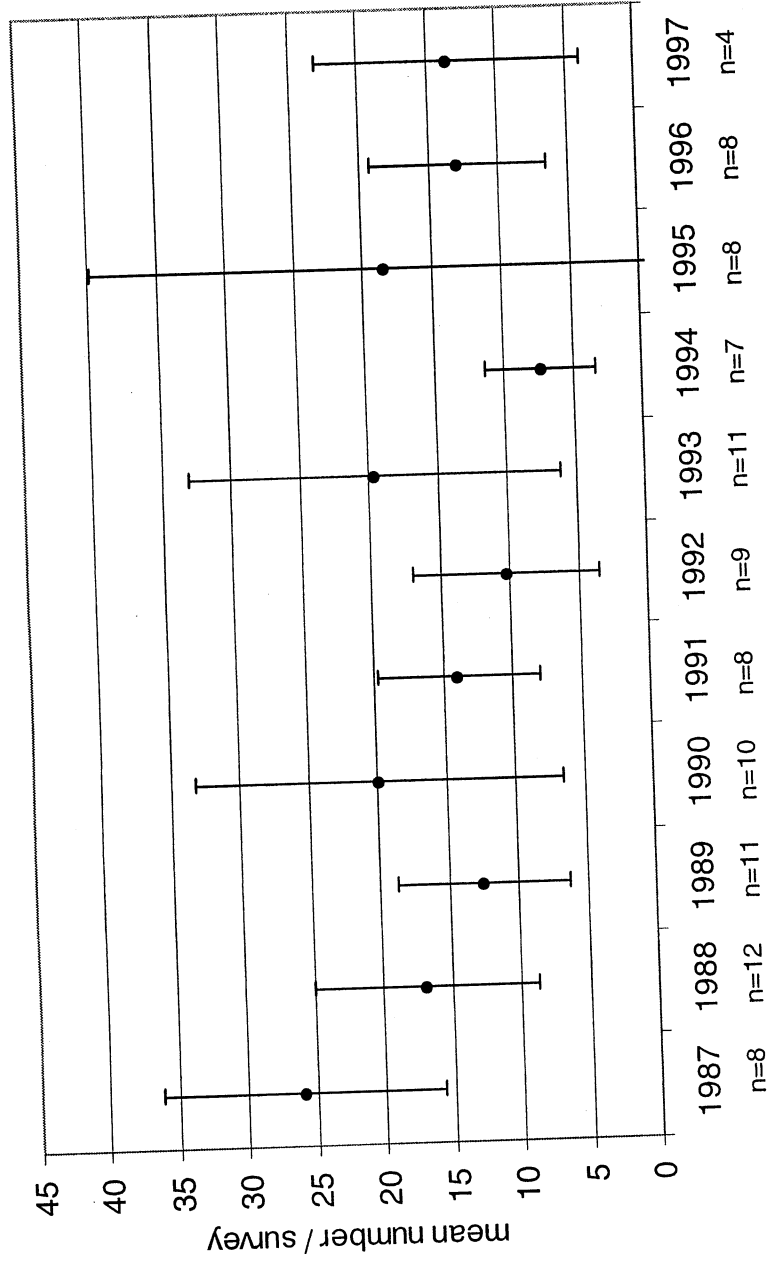
Trends in numbers of Roseate Spoonbill observed during wading bird foraging surveys in thirteen impoundments at MINWR from April 1987 through September 1997. Above, cumulative average density per survey. Middle, pattern of habitat use. Below monthly proportional habitat use.



Monthly and Yearly trends in average number of Roseate Spoonbill observed during foraging surveys at Merritt Island National Wildlife Refuge between April 1987 and September 1997. Points mark mean number per survey and bars give one standard deviation around mean.

Great Blue Heron – Although still common, Great Blue Heron was less abundant than most species of wading birds that occur on KSC/MINWR. Numbers of Great Blue Heron were fairly steady throughout the year, but differed significantly between impoundments. Although Great Blue Heron were most common in the group of impoundments that also had high abundances of other species of wading birds (e.g. T10L, T27B, T38, T27D, T33A) they used several other impoundments nearly as much (e.g. T10D, C2136, C21B, T24C). It may be more interesting to list the impoundments not heavily used by Great Blue Heron, namely T10K, T17, T9, and C15D. Nothing obvious stands out about this set of impoundments, except perhaps slightly smaller relative amount of open water habitat. However, this is not a fully satisfactory explanation for low use of these impoundments by Great Blue Herons, since other impoundments with similar relative amounts of open water habitat were more heavily used by them (e.g. C21B and T24C).

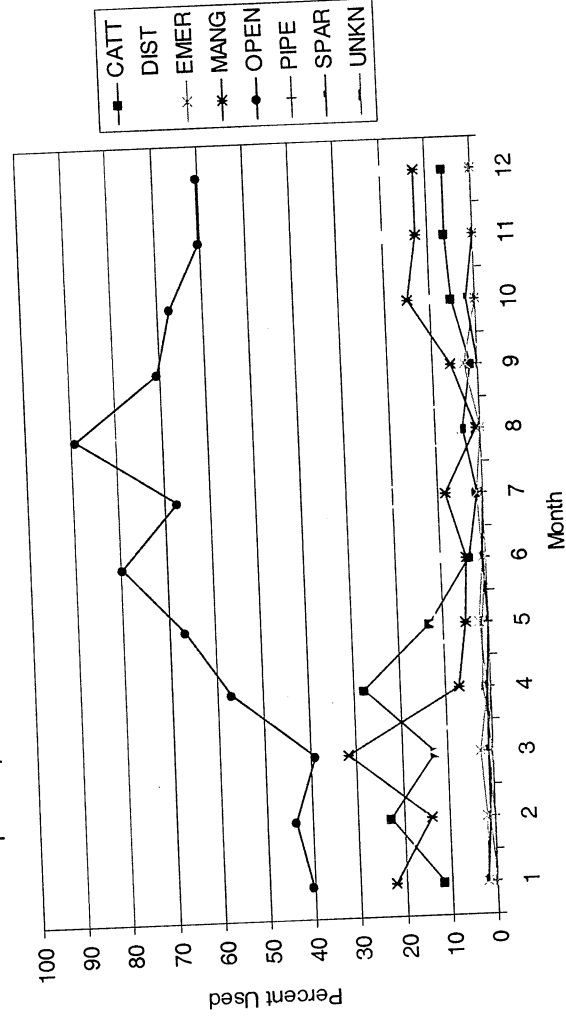
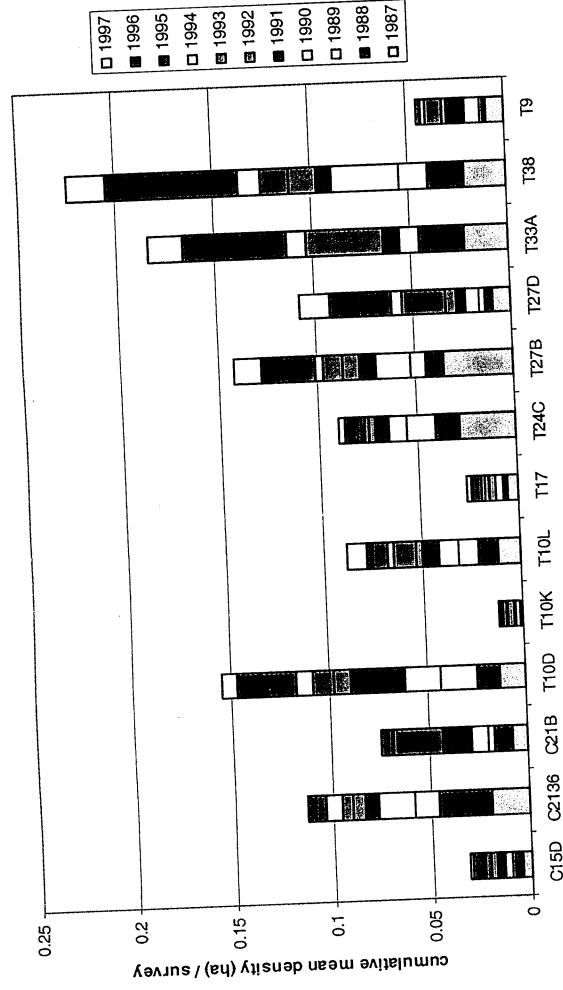
Great Blue Heron were observed foraging primarily in Open habitat within impoundments. During Spring, Great Blue Heron increased their use of other habitats slightly. Great Blue Heron was a common nesting species on KSC/MINWR, with fairly steady numbers of nests over the 11 years of data.



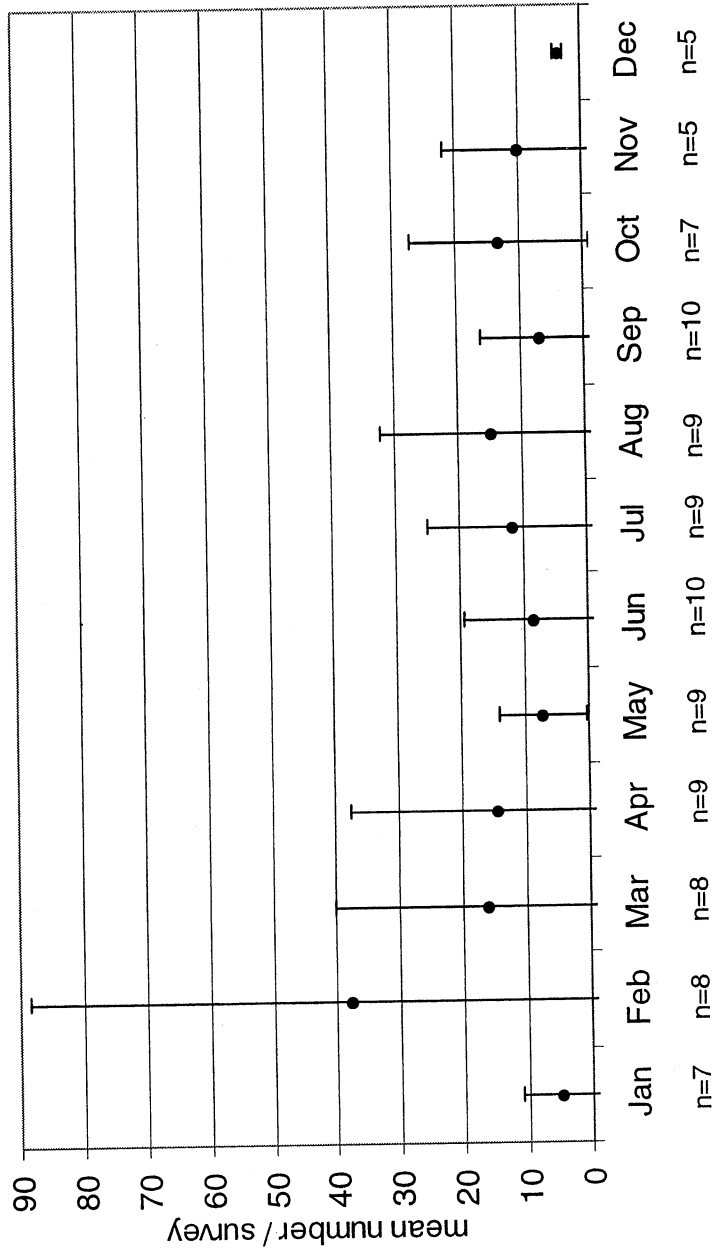
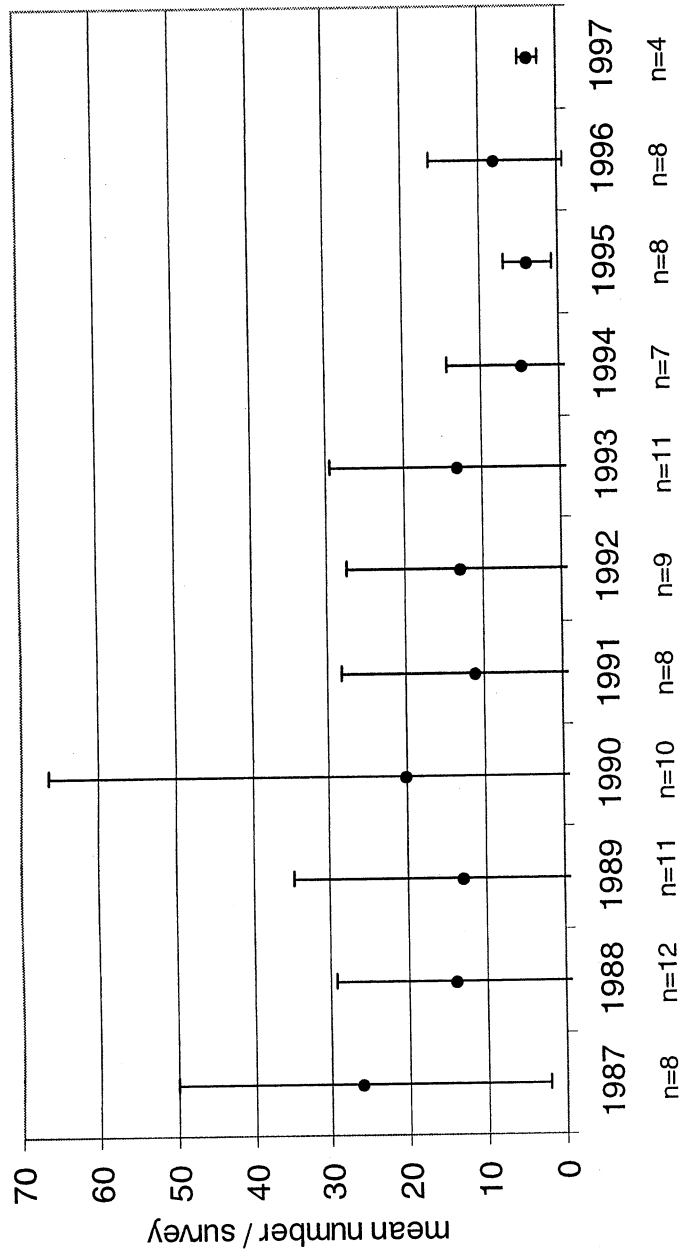
Monthly and Yearly trends in average number of Great Blue Heron observed during foraging surveys at Merritt Island National Wildlife Refuge between April 1987 and September 1997. Points mark mean number per survey and bars give one standard deviation around mean.

Little Blue Heron – Little Blue Heron was the third least abundant species observed on KSC/MINWR during foraging surveys. However, detectability of small dark wading birds is difficult during aerial surveys and thus the numbers recorded may underestimate the number of Little Blue Heron actually present. During foraging surveys, Little Blue Heron were much more abundant in some impoundments than others. Impoundments that stood out as having exceptional abundances of Little Blue Heron were T10L, T38, and T27B, and to a lesser extent, T27D and T33A. These same impoundments were also observed to have high abundances of several other species of wading birds. The number of Little Blue heron observed during foraging surveys appeared to decline slightly during the eleven years, although the trend was not statistically significant. The numbers of Little Blue Heron nests detected during the study was low, probably reflecting the lower detectability for this small dark bird.

During surveys Little Blue Heron were observed primarily in Open habitat. This may also be an artifact of detectability, since small dark herons are more visible in that habitat type than any others. Due to limitations of detection during foraging and nest count surveys, data for Little Blue Heron obtained from this study should be interpreted with caution. If more information is needed about Little Blue Herons on KSC/MINWR other methods of investigation should be considered.



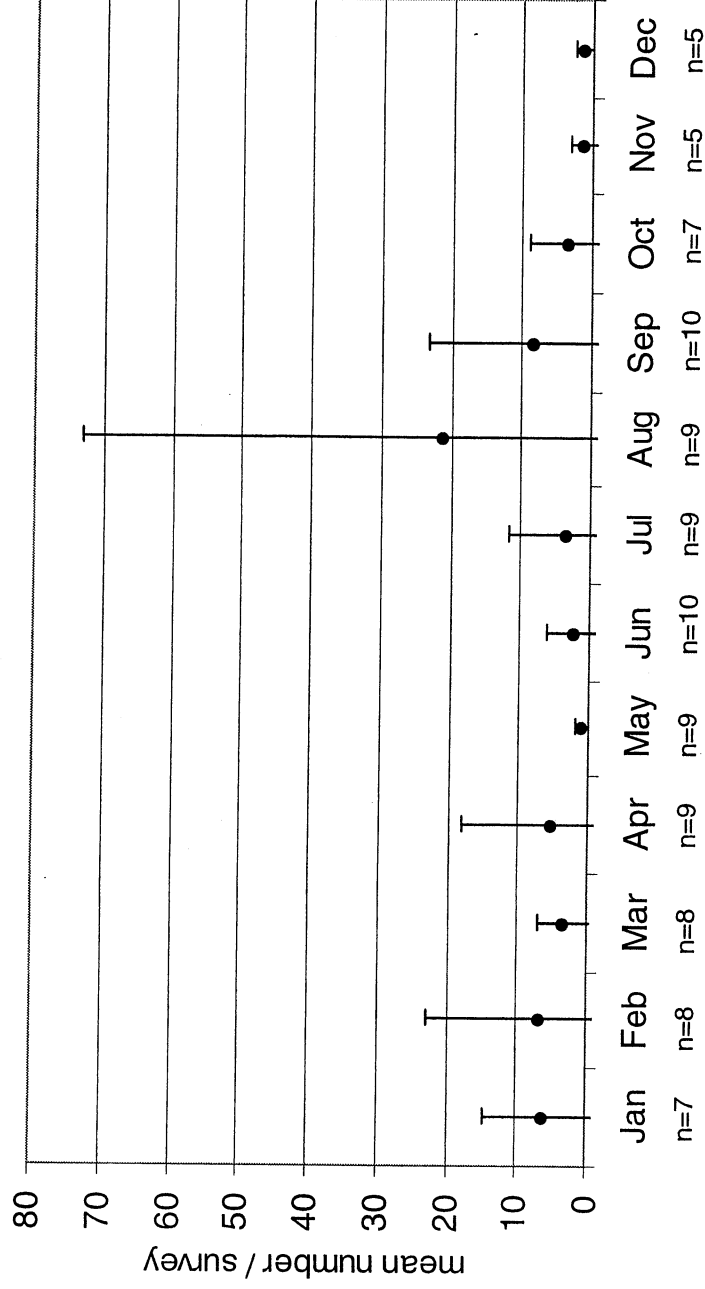
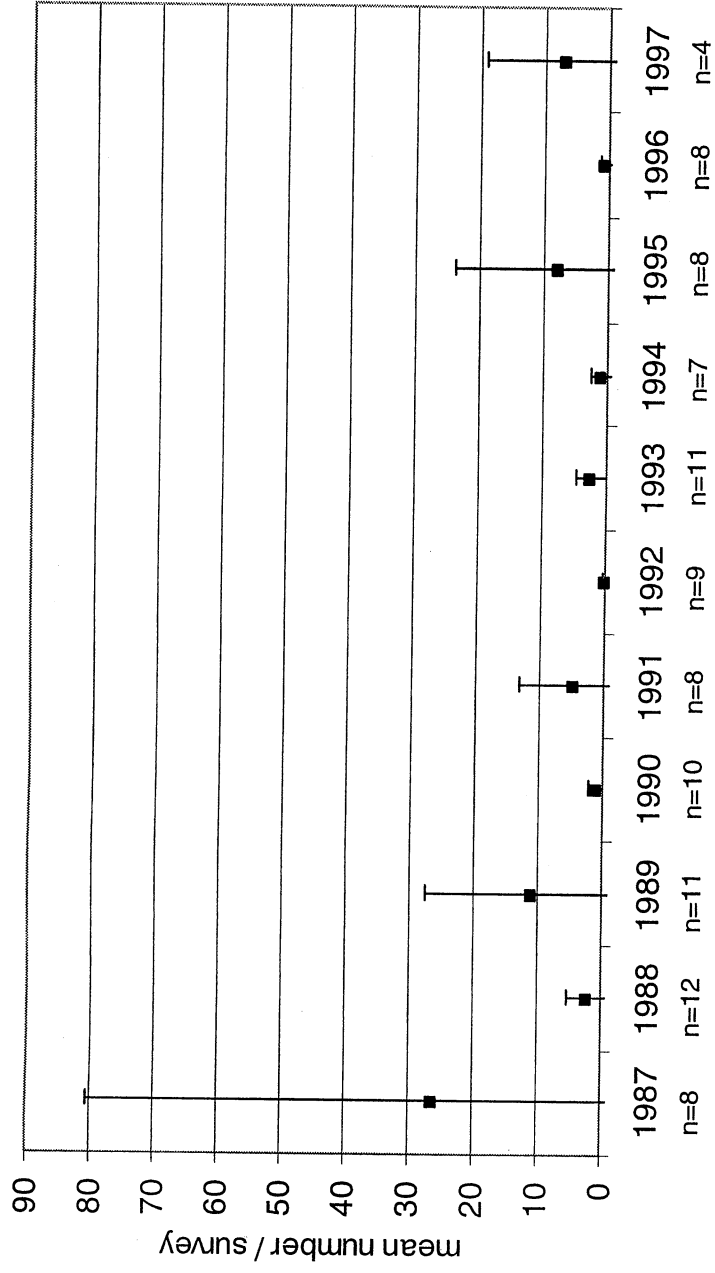
Trends in numbers of Great Blue Heron observed during wading bird foraging surveys in thirteen impoundments at MINWR from April 1987 through September 1997. Above, cumulative average density per survey. Middle, pattern of habitat use. Below monthly proportional habitat use.



Monthly and Yearly trends in average number of Little Blue Heron observed during foraging surveys at Merritt Island National Wildlife Refuge between April 1987 and September 1997. Points mark mean number per survey and bars give one standard deviation around mean.

Wood Stork – Wood Stork had low abundance during foraging surveys. Their numbers declined significantly after 1990, the year in which their nesting colony on KSC/MINWR failed due to a freeze that killed the mangrove trees at the site. Following 1990, the numbers of Wood Stork observed varied somewhat between years; in some years Wood Stork were observed much more frequently than in others. Wood Stork showed a strong differential use of impoundments on KSC/MINWR. Wood Stork foraging was concentrated in many of the same impoundments that were also observed to have high abundances of several other species of wading birds. They also used some impoundments that were less used by other species. In years when Wood Stork were most abundant, they seemed to use only a few of the impoundments, but those impoundments used varied between years.

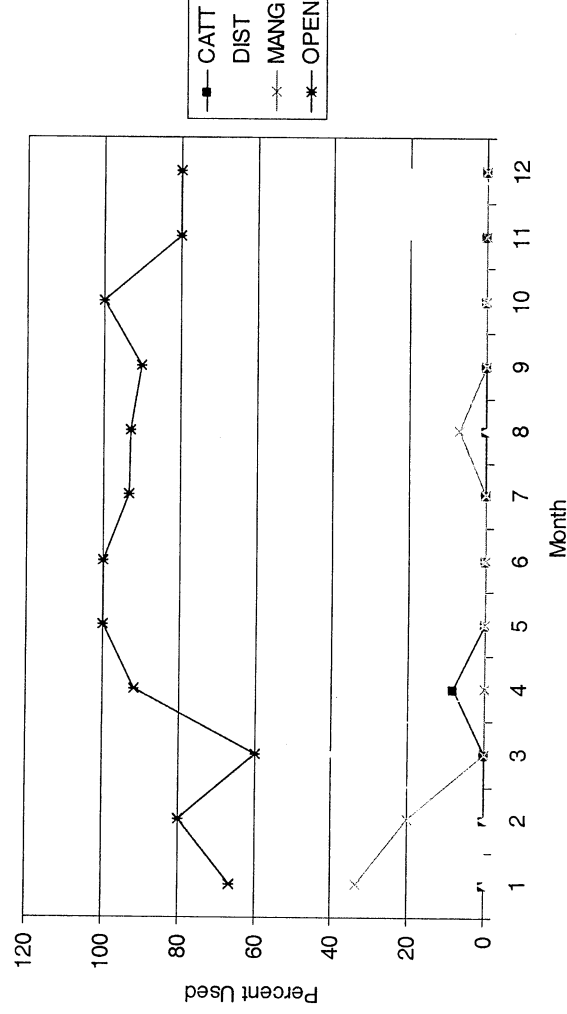
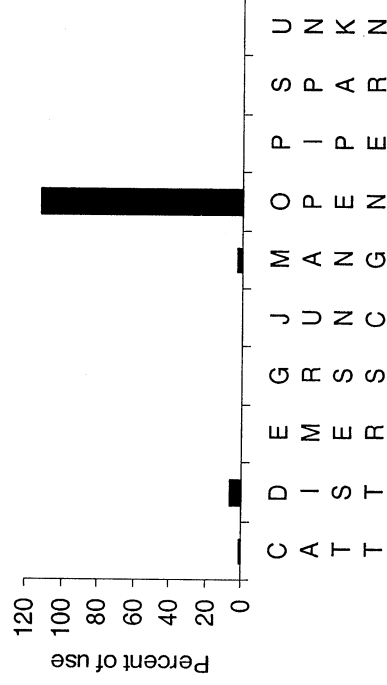
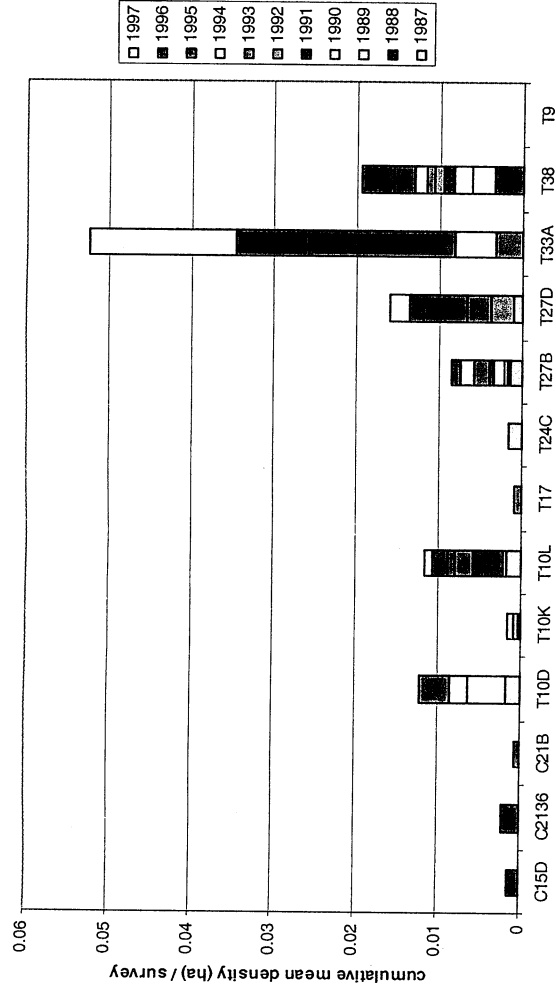
There was some evidence for seasonal differences in Wood Stork use of impoundments on KSC/MINWR, but the data was sketchy at best. Wood Stork were most often observed foraging in Open habitat. Wood Stork showed a shift to use of Mangrove and Distichlis in late Fall through Winter. This seasonal shift in habitat use coincided with a decrease in number of individuals present. Due to their preference for fresh water habitats the methods used in this study may not have adequately represented habitat use of Wood Stork at KSC/MINWR. Due to the decline in numbers of Wood Stork during recent decades this species should be closely monitored on KSC/MINWR. Other methods of investigation that focus more specifically on Wood Storks should be considered.



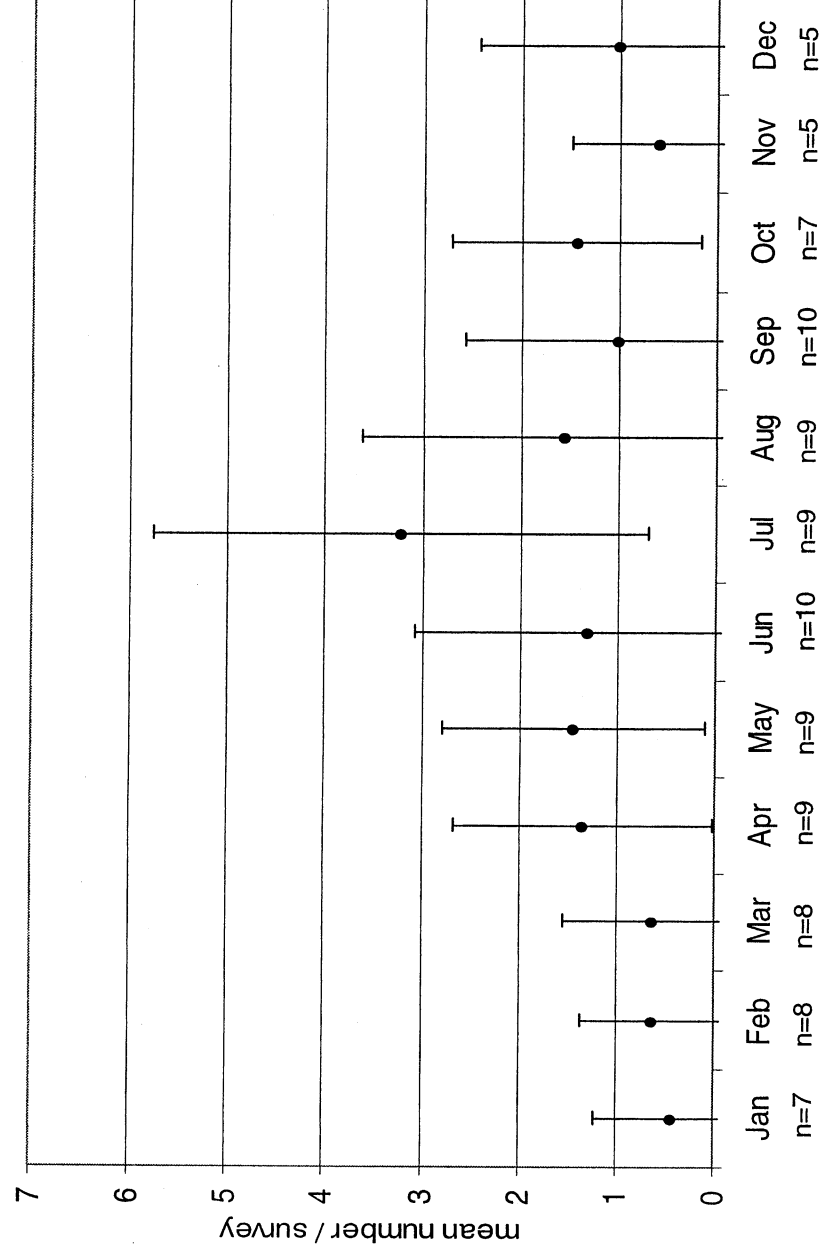
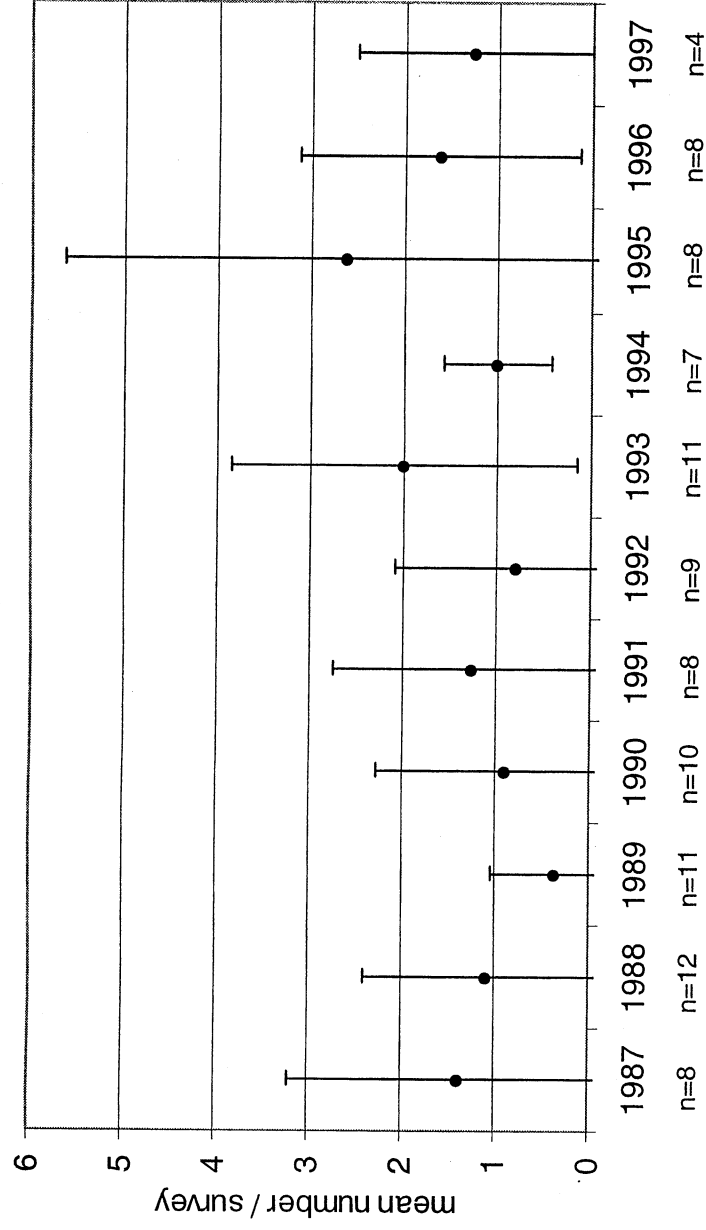
Yearly and monthly trends in average number of Wood Stork observed during foraging surveys at Merritt Island National Wildlife Refuge between April 1987 and September 1997. Points mark mean number per survey and bars give one standard deviation around mean.

Reddish Egret – Reddish Egret was the least abundant species of wading bird observed during foraging surveys; KSC/MINWR is near the northern limits of the species range on the Atlantic coast. No significant trend in the number of Reddish Egret was found during the 11 years of foraging survey data; this may have been due in part to the low numbers observed. During foraging surveys, Reddish Egret were much more abundant in some impoundments than others. Impoundments that stood out as having high abundances of Reddish Egret were T33A, T10L, T27D, T27B, and T38. Numbers of Reddish Egret were also high in T10D, an impoundment that was used less frequently by most other species. There were few clear yearly trends in the use of impoundments by Reddish Egrets. Some impoundments showed slight increases over the eleven years of survey data (e.g. T33A, T38), but others merely fluctuated over time (e.g. T10L, T27B, T27D). In the other impoundments numbers remained low throughout the eleven years.

Reddish Egret preferred Open habitat for foraging in impounded wetlands on KSC/MINWR. The apparent shift in habitat use that occurred in winter coincided with a reduction in numbers of Reddish Egret in this season; during this time Reddish Egret made relatively greater use of Mangrove and Distichlis habitat.



Trends in numbers of Reddish Egret observed during wading bird foraging surveys in thirteen impoundments at MINWR from April 1987 through September 1997. Above, cumulative average density per survey. Middle, pattern of habitat use. Below monthly proportional habitat use.



Monthly and Yearly trends in average number of Reddish Egret observed during foraging surveys at Merritt Island National Wildlife Refuge between April 1987 and September 1997. Points mark mean number per survey and bars give one standard deviation around mean.

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13. ABSTRACT (Maximum 200 words) This report summarizes results of the first eleven years of monthly aerial surveys of wading bird use of foraging habitats within impoundments on the Kennedy Space Center/Merritt Island National Wildlife Refuge. Some impoundments were used much more heavily by wading birds than were others. Analysis suggests that an increase in interspersions of open water and vegetated habitats is preferred foraging habitat. Many wading bird species increased their use of vegetated habitat in Fall and Winter when impoundments were flooded. The mean number of wading birds per survey was greatest during the Pre-nesting and Nesting seasons, declined during Post-nesting season, and was lowest during Winter when water levels within impoundments were high. During these times, shallow habitat along the IRL shoreline provided alternative habitats for wading birds. Various measures of monthly precipitation and impoundment water level were well correlated with the numbers of wading birds observed. Numbers of nesting attempts was steady during the study period, with the exception of an unusually high number of attempts in 1990. White Ibis accounted for over half of all wading bird nests counted. The mean number of nests per colony decreased during the study period, and the number of individual colonies increased.				
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